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edited by

P.G. Telford and H.M. Verma

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FOREWORD

MOOSE RIVER BASIN

The Mesozoic lignite and industrial mineral deposits of the Moose River Basin have been known for over a century but their resource potential has never been fully assessed. From 1975 to 1978 the Ontario Geological Survey carried out a program of drilling, outcrop reconnaissance, and geophysical surveys with the principal aim of providing a comprehensive evaluation of the mineral resources as well as upgrading the geoscience data base of the region. This report documents the 1975 to 1977 field program and laboratory studies (up to 1979) of material collected during that period. Surface and subsurface field data, petrographic analysis, and the results of extensive palynological determinations are reported. The interpretations based on this varied combination of geological disciplines greatly extend our understanding of the Mesozoic stratigraphy and economic geology of the Moose River Basin and will provide considerable encouragement to mineral exploration.

E.G. Pye,
Director
Ontario Geological Survey

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CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE–Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in co-operation with the Coal Association of Canada.

INTRODUCTION

by

P.G. Telford

In 1975 and the fall of 1977, the Ontario Geological Survey carried out drilling and outcrop reconnaissance programmes in two areas of the Moose River Basin, James Bay Lowland. This work, which was directed mainly to an assessment of Cretaceous lignite and industrial mineral potential of the region, revealed a large amount of new information on the Mesozoic geology of the basin. Preliminary results of the work have been documented in various Ontario Geological Survey Open File Reports (Rogers *et al.* 1975; Vos 1975; 1978; Telford, Vos, and Norris 1975; Verma, Telford and Norris 1978). In fall of 1978 further drilling was undertaken by the Ontario Geological Survey along the southern margin of the Moose River Basin between Coal River and Adam Creek (Telford and Verma 1978). The following collection of articles on the history, stratigraphy, petrography, palynology, and economic geology of the Mesozoic sediments of the Moose River Basin records the results of laboratory and other subsequent studies of lithological samples obtained during the 1975 and 1977 field activities. Additional analytical work is being carried out on Paleozoic and Pleistocene material also obtained during these programmes. Results of these studies will be published.

Geological investigations began in the James Bay Lowland, and more specifically the Moose River Basin, a century ago. However, a thorough geological study of the region has never been completed. The work has always been hampered by problems of difficult access, high costs, and lack of adequate exposures of the Mesozoic and underlying Paleozoic strata.

Drilling is the obvious means of circumventing the lack of surface exposures but it does involve considerable technical and other difficulties. These stem from the swampy terrain of the James Bay Lowland during summer months and the intense cold and variable weather conditions of the winter. During the winter, drilling operations are relatively problem-free from a technical viewpoint because of the frozen ground. However the cost of providing winter roads and suitable living quarters is high. During the summer months the drilling itself is more difficult, but the efficient use of helicopters alleviates many of the logistical problems.

The 1975 drilling operation took place during the winter months (January-March) and six holes (ranging from 46 m to 175 m in depth) were completed on an approximately north-northwest line extending from Smoky Falls at the south-central margin of the Moose River Basin (Photo 1.1). A seismic survey was done concurrently with the drilling. In the summer of 1975 a helicopter-supported reconnaissance was made of all known Mesozoic exposures in the Moose River Basin. Important Paleozoic and Pleistocene sections were also examined. The 1977 drilling programme was completed in October of that year and consisted of three relatively shallow holes (maximum 51 m in depth) on the east side of the Abitibi River, adjacent to the well-known lignite deposits at Onakawana. This was a helicopter-supported operation and was a follow-up to a ground and airborne electromagnetic survey done in 1976.

In order to maximise the use of samples obtained during the field programmes, and to develop a better understanding of Mesozoic stratigraphic relationships in the Moose River Basin, additional geological tools were sought. Two of these are described in this study. G. Norris made a comprehensive palynological analysis of supposedly Cretaceous age clay samples from the various drill holes. He recognized, for the first time, the existence of Jurassic age sediments in the central part of the Moose River Basin, and was able to establish firm regional correlations and a tentative biostratigraphic zonation of the overlying Cretaceous sediments. Of particular interest is the age determined for lignite found in several of the drillholes and its correlation with the deposits at Onakawana. A.P. Hamblin's petrographic study of the Pleistocene, Cretaceous, and Jurassic sands developed ideas on the provenance of these sediments and perhaps more significantly provided a means of distinguishing the different sand units. It is most important to have an independent method of recognizing the sand units of different geological age and origin as palynomorph assemblages are often absent from these sediments.

Taken together, the various studies, that have been completed thus far on the Moose River Basin, have produced a much clearer picture of the Mesozoic geology of the region. From this has followed a more reliable assessment of the economic potential of the region and recommendations for future work.

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History of Geological Exploration in the James Bay Lowland

by

H.M. Verma[1]

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[1]Engineering and Terrain Geology Section, Ontario Geological Survey.

ABSTRACT

The vast hinterland bordering the west coast of Hudson Bay has been the subject of geological exploration for nearly one hundred years. Although the cultural and geographic features were recorded by the fur traders and explorers of the 17th and 18th centuries, the basic geological framework was laid down by the Geological Survey of Canada and the Ontario Bureau of Mines towards the end of the 19th century. The early reports are concerned with the deposits of lignite, fireclay, kaolin, silica sand, gypsum, and iron. Since then, exploration has proceeded intermittently with some periods of feverish exploratory activity. The period of most active geological investigation was the late 1920s through to the early 1930s when the Ontario Department of Mines conducted an extensive programme of exploration, development, and feasibility studies of the economic mineral resources of the James Bay Lowland. Extensive drilling was carried out in the Onakawana lignite area.

Since 1966, the James Bay Lowland has again become the subject of active exploration by the Geological Survey of Canada, the Ontario Geological Survey and private enterprise. While the Geological Survey of Canada continued to build a broad regional picture of the entire Hudson Bay Lowland, the Ontario Geological Survey launched a fresh reconnaissance programme of geological and geophysical studies particularly of the Moose River Basin. Three drilling programmes, two geophysical studies and two outcrop reconnaissance surveys have been completed. At the same time the private sector is taking a serious look at the commercial development of Onakawana lignite for thermal power generation.

INTRODUCTION

The James Bay Lowland is the southern part of the flat, coastal plain, 200 to 300 kilometres wide, known as the Hudson Bay Lowland (Figure 1.1). The James Bay Lowland extends from the Nottaway River in the Province of Quebec to Cape Henrietta Maria. Within the James Bay Lowland the Moose River Basin was a basin of intermittant Phanerozoic sedimentation. Exploration of the region began during the days of the fur traders, explorers, and missionaries. These pioneers, often accompanied by Indian guides, made arduous canoe journeys into the inhospitable terrain via many of the rivers that drain into Hudson Bay and recorded in vivid detail their observations on all aspects of the land through which they travelled. Their accounts included detailed descriptions of the topography, vegetation, climate, culture, and geology. These accounts form the basis of much of the work being carried out by modern students of the Hudson Bay Lowland. Formal geological exploration of the James Bay Lowland was initiated almost a century ago and continues undiminished to this day.

It is not intended here to review all the important geological studies that have been done during the past nearly one hundred years. Even a brief discussion of each of these would be beyond the scope of this paper. Emphasis is placed here on the major developments in the history of exploration as they relate to

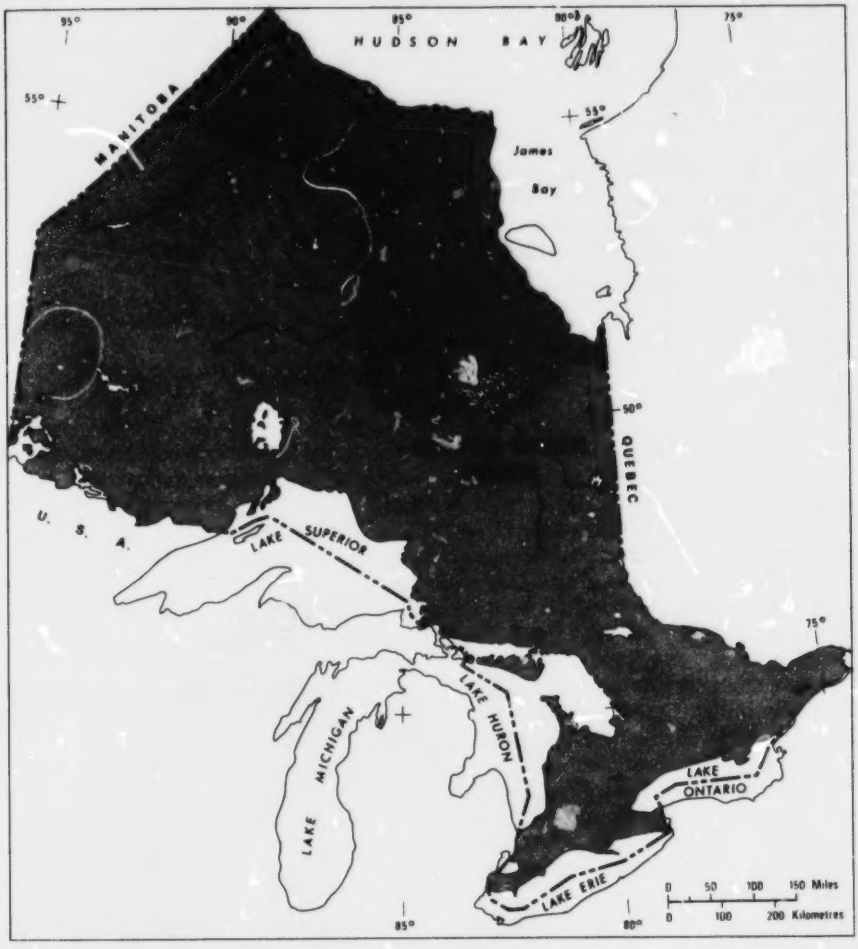

Figure 1.1–Distribution of the Hudson Bay and James Bay Lowlands.

the Paleozoic and Mesozoic geology of the Moose River Basin. Those wishing more details should refer to the bibliography compiled by Norris, Sanford, and Bell (1968) which lists most of the literature, up to 1967, dealing with the geology of the Hudson Bay Lowland. In addition, the proceedings of two important symposia (Hood 1969; Beals 1968) held by the Department of Energy,Mines,and Resources, Ottawa, contain important review papers on various aspects of the geology of the Hudson Bay Lowland. Since there is no ready source of reference for the post-1967 studies, these recent developments will be described in as much detail as possible. Some of the post-1967 developments can be found in an annotated bibliography compiled by Henley and Eyler (1976) which, in addition to listing the geological works, also deals with publications on a variety of other subjects including the Indians, and the Innuit, geography, rivers, soils, economic development and history.

THE EARLY YEARS

Much of the early geological work in the James Bay Lowland was related to the occurrence of lignite on the banks of Abitibi River near Onakawana, presently a remote railway siding on the Ontario Northland Railway, halfway between Cochrane and Moosonee (Figure 1.2). This occurrence was known to the inhabitants of the first English speaking settlement at Moose Factory in 1672. Lignite from the banks of the Abitibi River is reported to have been used in the forges at Moose Factory to manufacture tools. This gave rise to the name "Blacksmith Rapids" used in the early literature for the site known today as Onakawana.

The earliest known geological account of the Hudson Bay territories was given by Isbister (1855). However, it was towards the end of the 19th century and the early part of the 20th century that detailed exploration began in the James Bay area, first by the Geological Survey of Canada and later by the Ontario Bureau of Mines. The credit for laying down the basic geological framework of the Hudson Bay Lowland goes to Robert Bell of the Geological Survey of Canada who, between 1871 and 1912, wrote no less than 22 reports dealing with various geological aspects of the land surrounding Hudson Bay. Of particular interest are his reports for the years 1875 and 1877 (Bell 1877; 1879) in which the occurrences of lignite on the Missinaibi River, limonite on the banks of the Mattagami River, and other important industrial minerals elsewhere in the region were reported for the first time.

At about this time the Government of Ontario became interested in the economic development of the James Bay Lowland. Two important reports were prepared by E.B. Borron (1880; 1891) for the Legislative Assembly of Ontario. The first dealt with a part of the Basin of Hudson Bay, and the second with the Basin of the Moose River. Borron's observations of the lignite and silica sand-kaolin deposits of the Missinaibi River and the lignite outcrops on the Abitibi River were to form the basis of much of the later work in this area. The first detailed report on the economic resources of the Moose River Basin, incorporating much of the earlier work and the work done by the Ontario Bureau of Mines, was prepared by J.M. Bell (1904). The objective of this report was to determine

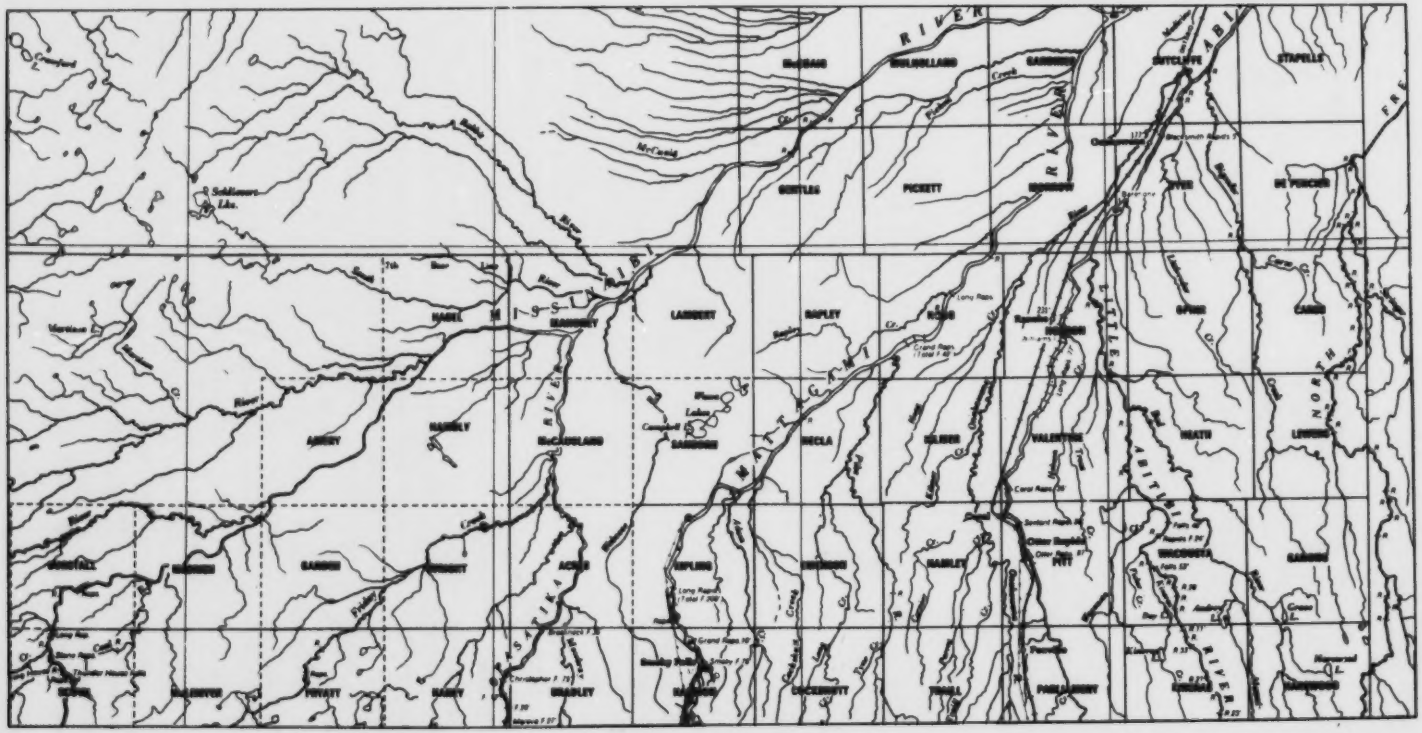

Figure 1.2–Important localities and areas of exploration activities in the James Bay Lowlands.

definitely whether the lignite occurrences were suitable for commercial use and to study the other known mineral deposits of gypsum, iron ores, clay, and shale.

It is interesting to note that in most of the early reports there are many references to the occurrences of lignite in the James Bay Lowland, giving the impression that deposits of this important fuel are abundant and widely scattered throughout the region. This in fact is not the case. In the Moose River Basin of the James Bay Lowland, beds containing carbonized plant material are of two types and belong to two different geological periods. One is the true lignite of the Cretaceous Mattagami Formation found in association with fireclays and silica sands. The other is more appropriately described as peat and is found in the Forest Peat Member of the Pleistocene Missinaibi Formation (Skinner 1973). In the early days of exploration of the James Bay Lowland the distinction between true Cretaceous lignite and the Pleistocene peat was not recognized. The majority of the exposures of 'lignite' reported in the early literature are actually peat deposits of Pleistocene age.

Baker (1911, p.223,230,237) considered all lignite deposits of the Mattagami River basin to be of Pleistocene age. Interestingly enough, Baker (1911, p.234) remarked that "...the lignites of the Moose region are, considering their recent age, in a remarkably advanced state of carbonization..." In retrospect this is not surprising, for these were much older (i.e. Cretaceous) in age. One of the primary objectives of Baker's studies was to investigate reports circulating during the winter of 1909-1910 that real "coal" had been found on the Mattagami River resulting in staking of several claims. When Baker reported that the so called "coal" offered few economic possibilities no further staking took place. Baker's report is an important document for it describes, in greater detail, the iron deposits of the Mattagami River, first reported by Bell (1877).

It was during an investigation of the clay and shale deposits on the Mattagami River by Keele (1920) that the first recognition of deposits of Cretaceous age was made. The clays were found associated with lignite and silica sands and Keele, for the first time, recognized the age of the clay-lignite-silica sand deposits as "undoubtedly of pre-glacial age, of more recent origin than Upper Devonian". A collection of plant fossils from a sandstone bed included in the clays was identified as "...not younger than Kootenay, but may be older...", by the paleobotanists of the United States Geological Survey. Thus the name Mattagami series was introduced in the literature for the Cretaceous clays of the Mattagami River. Dyer (1929) went on to define the Mattagami Formation which included the associated lignite and silica sands. The Lower Cretaceous age of the Mattagami Formation has since been confirmed by several paleobotanical studies e.g. W.A. Bell 1928; Hopkins and Sweet 1976; Norris, Telford, and Vos 1976. Keele, through a series of publications during the years 1920-1922 laid the foundation for many of the future activities centered on the clay and silica sand deposits of the Missinaibi and Mattagami Rivers (see below). About the same time attention was focussed also on the pre-Cretaceous rocks of the James Bay Lowland. Following Parks' (1899; 1904) early work, Savage and Van Tuyl (1919), Williams (1920), and Kindle (1924) produced the basic framework for the Paleozoic stratigraphy of the region and Cross (1920) studied the iron ore deposits of the Abitibi-Mattagami area.

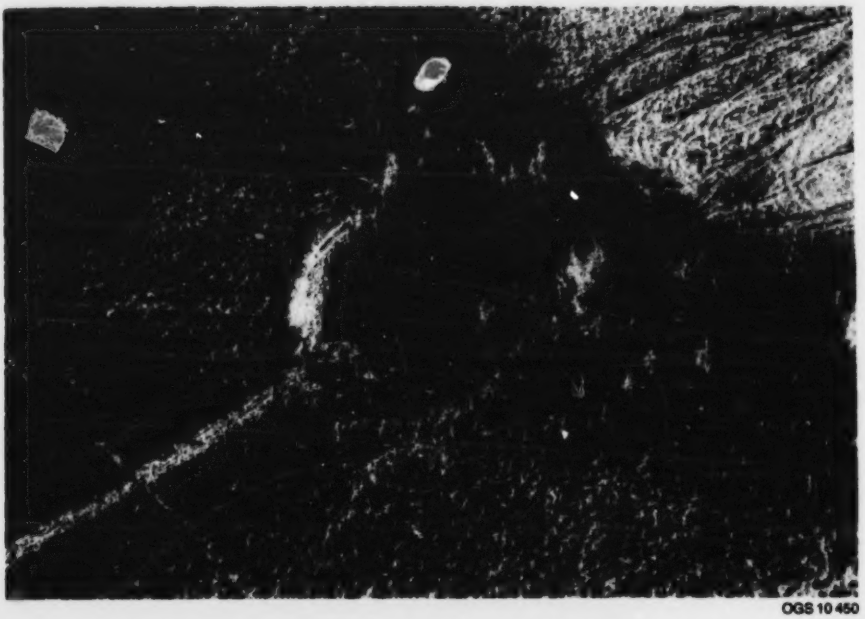

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Photo 1.1–Aerial Photograph of the location of shaft "W" in the Onakawana Lignite Field.

1926 TO 1966

In 1926, the Ontario Government regained interest in the Onakawana lignite deposits and withdrew from staking a 2840 km² area in the vicinity of Onakawana. In 1928, testing of a seven ton sample of lignite collected from the Abitibi River outcrop near Onakawana showed similarity with Saskatchewan lignite and suggested a potential for commercial fuel. The ensuing period of six or seven years constitutes a most productive period in the history of exploration of the James Bay Lowland. It was during this time that officers of the Ontario Bureau of Mines carried out an extensive programme of exploration, development, and feasibility studies of all the major mineral resources of the James Bay Lowland, including detailed studies of the Onakawana lignite based on extensive drilling and reports on industrial minerals such as limestone, gypsum, kaolin, and refractory clay.

At Onakawana, the Ontario Bureau of Mines drilled 116 holes totalling 5200 m. In addition, two shafts were sunk. Shaft No.1 near the Abitibi River was 23 m deep. Shaft "W" near the Onakawana River was 41 m deep with drifts extending 389 m (Photo 1.1). In 1930, the first drillhole to penetrate the entire sedimentary section in the Moose River Basin was put down in the middle of

the Onakawana area. This was Drill Hole "A" (Dyer and Crozier 1933a) which was to form the basis of much of the later understanding of the stratigraphy of the Moose River Basin. It was during this period of extensive exploration that the first geophysical studies, aimed at detecting underground lignite, were reported by Gilchrist (1932) and Hawkins (1933). The studies related to the exploratory work for lignite in the Onakawana area are documented in the works of Dyer (1929; 1930a; 1930c; 1931a; 1931b; 1932b), Dyer and Crozier (1933a), Gilmore (1930), Haanel and Gilmore (1933). In addition a study was also conducted by the Ontario Research Foundation on the technical and economic factors involved in the commercial development of the lignite deposits. This study, reported by the Ontario Research Foundation (1933), did not recommend any immediate commercial development. It did, however, recommend research toward the use of lignite in locomotive and industrial and commercial furnaces.

The Geological Survey of Canada also conducted a thorough study of the Mesozoic and Pleistocene deposits of the lower Missinaibi, Opasatika, and Mattagami Rivers as evidenced by the work of McLearn (1927) wherein, for the first time, a distinction was made between the Cretaceous lignite and the Pleistocene peat. Fuel analyses of samples collected by McLearn finally established that the Pleistocene peat had one-half to one-third the calorific value (B.T.U.) of the Cretaceous lignite. This, combined with its patchy occurrence, made it a less serious contender for large scale mining operations.

In the late 1920s and early 1930s, concurrent with the thorough exploration for lignite in the Onakawana area, great progress was also being made towards an understanding of the distribution, nature, and development potential of the iron ores, clays, silica sands, and other industrial minerals of the Moose River Basin. With regard to silica sand, kaolin, and fireclay, attention was focussed on three separate areas: (i) the Missinaibi River Deposits (McBrien Township); (ii) the Mattagami River Deposits (Kipling Township); and (iii) the Onakawana deposits (Dyer, Morrow, and Sutcliffe Townships). Of these the Kipling Township deposits, situated at the foot of Long Rapids on the Mattagami River, are the only ones in the Moose River Basin which have been developed to produce fireclay and silica sand. The deposits on the east side of the river were developed by the Northern Ontario China Clay Corporation while those on the west side were developed by General Refractories Products Limited and included the sinking of two shafts (McCarthy Shafts 1 and 2). Production in 1942-43 from the deposits of the west bank amounted to 86 tons of silica sand and 898 tons of fireclay. Giblin (1970) gave results of 1970 drilling in this area. The Missinaibi River deposits are now held by Algocen Mines Limited. A winter road from Hearst leads to the Algocen camp on the banks of the Missinaibi River. This area has also undergone extensive sampling and drilling, some as recent as 1970 (Smith and Murthy 1970). The reserves known to date are about 200 million tons.

Important contributions towards the understanding of all the above mentioned silica sand, kaolin, and fireclay deposits have been made by Dyer (1928; 1929; 1930a; 1930b; 1931b; 1932a; 1932b; 1933), Dyer and Crozier (1933a; 1933b); Dyer and Montgomery (1930), Montgomery (1930a; 1930b; 1933), Montgomery and Watson (1929), Crozier (1933), Westman (1933), Hilder (1935), and Davey (1932).

The poor economic conditions of the post-depression era resulted in the ter-

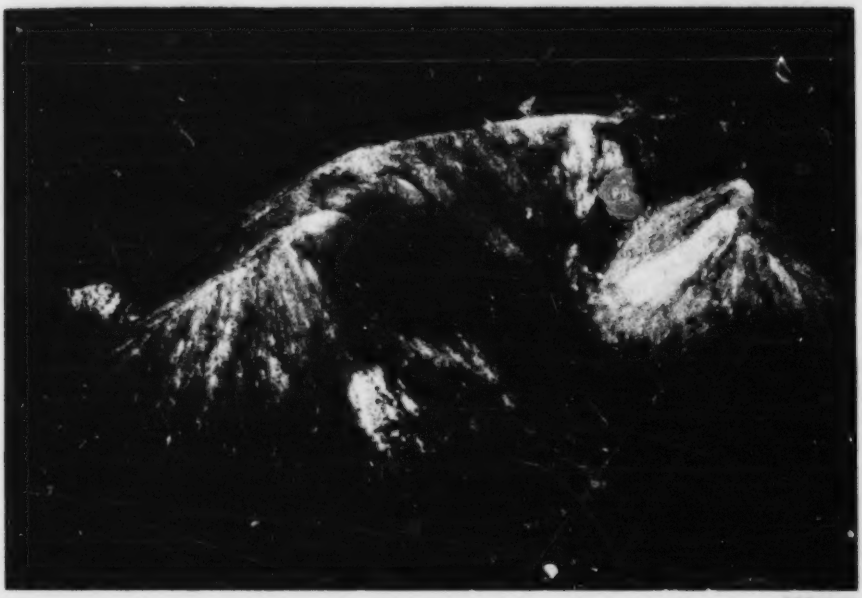

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Photo 1.2–Aerial Photograph of the stockpile of Lignite on the west bank of the Abitibi River near Onakawana.

mination of all exploratory activities at Onakawana but the war years saw a rejuvenation of interest. The James Bay extension of the Timiskaming and Northern Ontario Railway (now the Ontario Northland Railway) had reached Onakawana in 1930 and Moosonee in 1931. This railway greatly facilitated access to the Onakawana area. In fact the post-war development at Onakawana was carried out under the aegis of the Timiskaming and Northern Ontario Railway, and an additional 182 drill holes, totalling 5120 m were put down. A small area near the railway line containing an estimated 10 million tons of lignite was demarcated for commercial development. In 1943, the Fuel Commission of Ontario was established and it recommended that the deposit be put in a condition to meet the fuel shortage expected in 1945-46 (Ontario Fuel Commission 1944). Between 1945 and 1946, a pit was excavated between the Abitibi River and the railway line and 3000 tons of lignite were stockpiled (Photo 1.2). At the same time, a 100 horse power return tubular boiler was installed along with associated processing plant, garage and machine shop, and pump houses (McLaren 1948). After nearly fifty years of exploratory work, this was the closest that Onakawana came towards a full scale commercial development.

In 1946, after an on-site examination, a Select Committee of the Ontario Legislature recommended that, in view of the absence of any substantial demand for lignite fuel in the industrial markets, it was uneconomical to continue the development at Onakawana. Consequently, in 1947, all operations at

Onakawana were discontinued and the plant and equipment removed. The foundations of these buildings and some of the discarded machinery can still be seen on the banks of the Abitibi River at Onakawana.

The post-1947 lull in activities at Onakawana was to last for nearly twenty years. At the regional level, however, the exploration of the Moose River Basin was continued by the Ontario Department of Mines and other agencies. The Ontario Department of Mines drilled 3 deep holes to the Precambrian basement. These are: Campbell Lake (310 m), Jaab Lake (552 m) and Puskwache Point (468 m). The 61st Annual Report of the Ontario Division of Mines (1953) contains contributions by Martison, Wilson, Dyer, Crozier, Gerrie, Hogg, Satterly, and Wilson, reflecting the drilling activities. This report also includes a comprehensive account of the stratigraphy of the James Bay Lowland, as well as comments on the petroleum potential of the area.

During 1966, another regional study called "Operation Kapuskasing", was undertaken by the Ontario Department of Mines. This study consisted of a helicopter-supported geological survey of the geology and mineral resources of about 72 500 km^2 of Hudson Bay Lowland (Bennett *et al.* 1967). Also in 1966, Alberta Coal Company acquired a licence of exploration for about 1036 km^2 area around Onakawana. The company carried out extensive drilling (133 holes totalling 5791 m) with the objective of demarcating the field boundaries and establishing reserve quantity and quality of lignite in the area. A hitherto unknown deposit, called Portage Field, was discovered north of Onakawana during this investigation.

POST 1966 ACTIVITIES

Following an aeromagnetic survey of the Hudson Bay region in 1966 (MacLaren *et al.* 1968), the Geological Survey of Canada carried out an air supported geological reconnaissance survey of about 337 000 km^2 of the Hudson Bay Lowland (Operation Winisk; Sanford, Norris, and Bostock 1968). Important results of this programme included reports on the Quaternary stratigraphy of the Moose River Basin (Skinner 1973), Ordovician strata of the Hudson Bay Lowland (Cumming 1975), Devonian stratigraphy of the Hudson Platform (Sanford and Norris 1975), Devonian palynology of the Moose River Basin (McGregor *et al.* 1970; McGregor and Camfield 1976; Playford 1977), and Mesozoic deposits and coal of the Hudson Bay Lowland (Price 1978).

The world-wide energy shortage of the early 1970s rejuvenated efforts to reassess Ontario's reserves of fossil fuels and to decrease provincial dependence on imported coal. In 1972, the Ontario Government, Ontario Hydro, and Onakawana Development Limited (a subsidiary of Manalta Coal Limited, the successor of Alberta Coal Company) entered into an agreement to undertake a feasibility study on the development of the Onakawana lignite deposit. The results of this study by Shawinigan Engineering Company (1973) were published by the Ontario Ministry of Natural Resources. This study concluded that the development of Onakawana for generation of thermal power generation was a viable prospect. The feasibility study by Onakawana Development Limited, as well as a recalculation of tonnages on the basis of compilation of data

from all drill holes by Trusler *et al.* (1974), indicated that the total recoverable reserves are about 189 million tons from a total in place quantity of about 221 million tons. Three lignite fields were outlined. These are: Main Field, East Field, and Portage Field (see Figure 5.1). The reserves are distributed among the three fields as follows:

Main Field	163.0 million tons
East Field	11.7 million tons
Portage Field	14.3 million tons
Total	189.0 million tons

In examining Onakawana as a possible source of energy, environmental concerns have not been ignored. In January 1973, a special task force (Task Force Onakawana) with representatives of various Ontario Ministries, Ontario Hydro, the Conservation Council of Ontario, and local representatives from Moosonee, produced a report on the possible environmental effects of mining of the Onakawana lignite. The Task Force concluded that, on balance, the local and regional effects of developing this resource could be advantageous provided appropriate steps were taken to maximize the benefits to the local people and to minimize the adverse environmental effects (Task Force Onakawana 1973). It was felt that strip mining followed by proper reclamation would provide better drainage in the swampland and the resulting environment would be a better habitat for wild life than it is at present.

During 1977, Onakawana Development Limited continued to update their engineering and feasibility studies of the Onakawana area. The purpose of this work was to evaluate the economic viability of several modes of power plant generation based on varying capacities and tonnages of lignite. Included in this study was a major investigation by Golder Geotechnical Consultants Limited to evaluate the geotechnical and hydrological conditions on the site. Onakawana Development Limited was granted a 21 year lease, effective February 1, 1978, giving it the right to mine, stockpile and process lignite. Under the terms of the lease, the company is required to establish within seven to nine years, or longer if approved, a mining operation which will mine, produce, sell, or otherwise utilize not less than one million tons of mined lignite each year thereafter.

Limited petroleum exploration was also carried out during the early 1970s in the James Bay Lowland. A consortium of companies headed by Aquitaine of Canada Limited drilled several deep holes (to the Precambrian basement) in the Moose River Basin. One of these, Hambly No.1 (Aquitaine Sogepet *et al.* 1973), was put down in Hambly Township northwest of Smoky Falls and encountered an important complete section of the Lower Cretaceous Mattagami Formation (see Telford, this report). In 1974, the Aquitaine Sogepet group drilled a series of shallow holes in the Ranoke area, south of Onakawana (File No. 83-1-118, Aquitaine Company of Canada Limited, Assessment Files Research Office, Ontario Geological Survey), providing much new data on the Devonian stratigraphy of the basin.

In 1975, the Ontario Geological Survey launched a fresh programme of geological and geophysical investigation of the Mesozoic sediments in the Moose River Basin. To date, three drilling programmes (Rogers *et al.* 1975; Verma, Telford, and Norris 1978; Telford and Verma 1978), two geophysical surveys (Utard 1975; Scintrex Surveys Limited 1976), and two outcrop reconnaissance surveys (Telford *et al.* 1975; Verma and Telford 1978) have been completed.

OGS 10 482

Photo 1.3–Photograph showing the winter road and drill rig at location of drillhole 75-02.

The Winter 1975 drilling programme (Rogers *et al.* 1975) (Figure 1.3, Photo 1.3) comprised upgrading an existing road, building a new winter road, drilling and sampling of six holes in a general north-northwest line extending from Smoky Falls to the northern boundary of the supposed subcrop area of Mesozoic sediments, and geophysical studies mainly along the winter road. An existing winter road, 40 km long from Smoky Falls to Hambly Township was upgraded. A new extension of this road was built for another 72 km to the Kwataboahegan River (Figure 1.3). This programme of road construction commenced on January 7, 1975, and was completed on March 28, 1975. The specifications for the road were that it should be at least 5 m wide, as straight as possible, and suitable for use with a 5 ton truck. About 12 men working in two shifts, 24 hours a day, were involved. The major equipment used were one D7E bulldozer with a shearing blade and two smaller bulldozers for dragging. Ice bridges had to be built on the Opasatika and Missinaibi Rivers. Some difficulties were experienced in the crossing of these two major river owing to steep banks.

The six drillholes ranged in depth from 46 to 175 m. Holes 1 to 3 were drilled with a heavy duty diamond drill and holes 4 to 6 with a Nodwell-

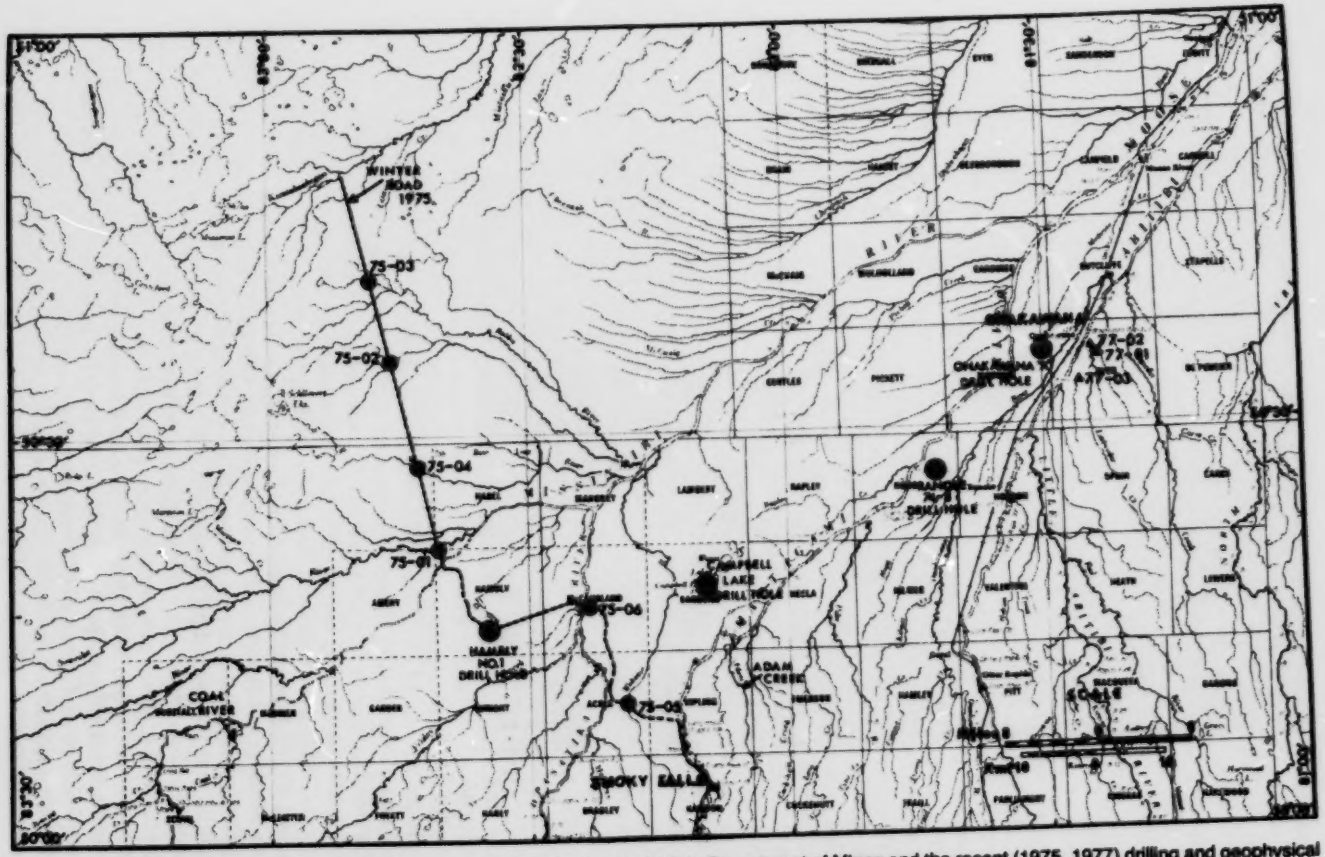


Figure 1.3–Map showing the location of deep holes put down by the former Ontario Department of Mines and the recent (1975, 1977) drilling and geophysical programmes of the Ontario Geological Survey.

mounted Acker drill, designed to sample deep overburden and bedrock. A reverse circulation method using 69 mm diameter standard Drilco dual tube rods was employed to obtain chip and slurry samples at intervals of about 2 m. The drills were operated continuously on two, 12 hour shifts. The drilling started on February 4, 1975 and was completed on March 27, 1975.

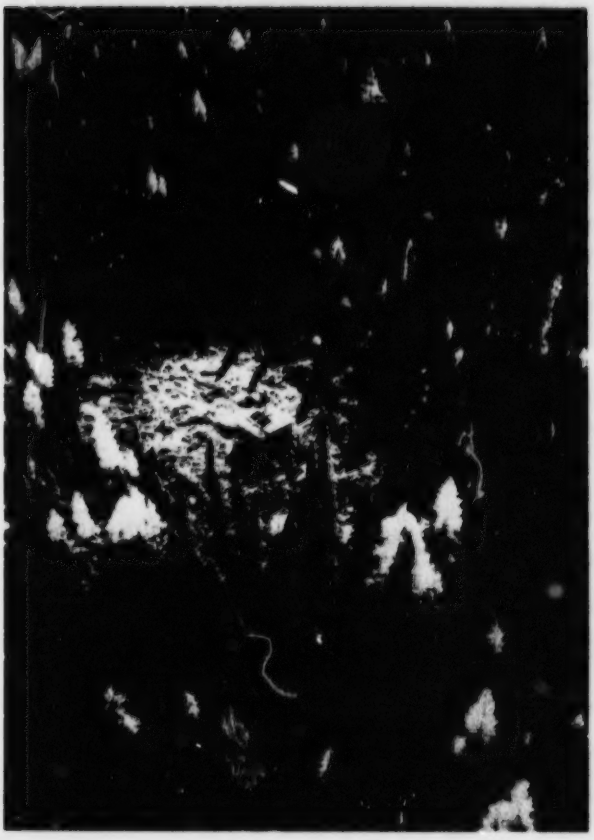
The geophysical studies consisted of a seismic survey for 72 km and a resistivity survey for 84 km. Both types of survey were carried out along the road north of Hambly Township base line and a resistivity survey was also conducted along the base line. Eight kilometres of combined surveys were done in parts of the road south of Hambly Township base line where the road was straight for at least 2 km.

During the summer of 1975, a helicopter supported outcrop reconnaissance survey of the Moose River Basin was carried out and the lignite deposits at Onakawana were re-examined (Telford *et al.* 1975). The objective of this work was to determine which of the earlier reported occurrences of "lignite" outside Onakawana were true lignites worthy of follow-up studies. It was determined that, except for the reported occurrences along Coal River where it meets the Missinaibi River, and those of the Mattagami River and its tributary Adam Creek, most of the other occurrences were of Pleistocene peat. Palynological analyses of samples collected from outcrops of the Mattagami Formation along the Mattagami River near Smoky Falls suggested at least a late Middle or Late Albian (Lower Cretaceous) age for the unit (Norris *et al.* 1976).

In 1975-76 another geophysical survey was carried out over the Onakawana lignite fields (Scintrex Surveys Limited 1976). The purpose of this work was to determine whether existing geophyscial methods, particularly geo-electric techniques (ground as well as airborne) can be used as search tools to locate near surface deposits of the Onakawana type. The ground resistivity survey indicated that there was no appreciable difference between the resistivity of the lignites and the clays associated with them. The airborne electromagnetic surveys indicated two regions of relatively high conductivity, one to the west of the Ontario Northland Railway containing "within its confines" the known lignite fields, and another area immediately to the east of the Abitibi River. The second zone included three anomalies and Scintrex considered them to be correlative with the anomalies over the known lignite fields at Onakawana.

In the Fall of 1977, three shallow holes were drilled on the anomaly locations east of the Abitibi River (Verma *et al.* 1978). In this operation, the equipment was transported to Onakawana by rail car and camp was established at the Onakwana railway siding. The movement of men and equipment between camp and drill sites was by a Bell 206L helicopter. Hole 77-01 was 46 m deep (Photo 1.4), 77-02 was 50 m and 77-03 was 51 m. Sampling was done by split spoon sampler at intervals of about 2 to 3 m as well as by BQ wire line core barrel giving continuous core recovery. The drilling commenced on October 11, 1977 and was completed on October 22, 1977. This investigation did not result in identification of significant quantities of lignite east of Abitibi River, but important stratigraphic information was obtained which will be useful in planning future exploration work in the Moose River Basin. Subsurface stratigraphy on the east side of the Abitibi River is significantly different from that on the west side, with Devonian bedrock forming local structural highs.

In late summer of 1978 the third major Mesozoic drilling programme was



OGS 10 453

Photo 1.4–Aerial photograph of drill rig on drillhole 77-01, east of Abitibi River.

carried out. While preliminary results have been documented (Telford and Verma 1978), full details of the operation were not available for release at time of writing (January, 1979). Eight holes, totalling about 1176 m, were drilled in a general east-west direction along the southern margin of the Moose River Basin between Hecla and McBrien Townships. At the same time, an outcrop sampling and reconnaissance programme was carried out along Adam Creek in Kipling Township (Verma and Telford 1978). Several of the drillholes encountered lignite seams and an *in situ* lignite outcrop was discovered in the bed of Adam Creek. Considerable study and laboratory analyses are presently being carried out on samples (core and chips) obtained during the drilling, and the results are to be transmitted in future reports of the Ontario Geological Survey.

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Mesozoic Stratigraphy of the Moose River Basin

by

P.G. Telford[1]

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ABSTRACT

Unconsolidated Mesozoic sediments are present in the southeastern part of the Moose River Basin, James Bay Lowland. Geological studies have been carried out intermittently in this area for nearly a century, but between 1975 and 1977 the Ontario Geological Survey implemented a major new programme of drilling, geophysical, and field mapping activities with a view to assessing the lignite and industrial mineral resource potential of the Mesozoic sediments. Two lithostratigraphic units have been distinguished. The Mistuskwia Beds (Middle Jurassic) occur toward the central part of the basin and consist of varicoloured calcareous clays and thin horizons of grey to white, fine to medium grained, calcareous, quartz sands. The maximum known thickness of the unit is 19.4 m. Disconformably overlying the Mistuskwia Beds is the Lower Cretaceous Mattagami Formation which has a maximum known thickness of 121.4 m, and consists of a variable sequence of varicoloured clays, quartz sands, and both detrital and *in situ* lignite. This unit is restricted to the marginal areas of the Moose River Basin and deposition took place in two phases. The earlier phase included the accumulation of the important lignite deposits at Onakawana, while sediments of the later phase include pure quartz sands and kaolinitic clays.

INTRODUCTION

LOCATION AND ACCESS

The Moose River Basin is a Phanerozoic sedimentary basin covering about 100 000 km^2 of the James Bay Lowland (Figure 2.1). It is bounded approximately by Latitudes 50°05′ and 52°30′ North and Longitudes 78°50′ and 84°45′ West. The basin lies mainly within the District of Cochrane, northeastern Ontario, with small easterly extensions into the Province of Quebec and to Akimiski Island in James Bay.

Of particular interest to this study is the southeastern portion of the basin where the Paleozoic bedrock is overlain by Mesozoic sediments. This area, bounded approximately by Latitudes 50° and 51° North and Longitudes 80°15′ and 83°45′ West, is centred about 150 km southwest of Moosonee and lies within the Smoky Falls (42-J) and Moose River(42-I) 1:250 000 NTS map areas. It is crossed by several major north-flowing watercourses, including the Missinaibi, Mattagami, and Abitibi Rivers, which are tributaries of the large Moose River. The southern extent of the Mesozoic sediments coincides with the southern margin of the Moose River Basin and is demarcated by an abrupt physiographic change from flat swampy lowlands to more rugged uplands of the Precambrian Shield (Photo 2.1). Except for the Spruce Falls Pulp and Paper Company community at Smoky Falls and some Ontario Hydro installations, there are no settlements within the area. The closest important population centre is Moosonee near the mouth of the Moose River on James Bay. Highway 11, the closest major road, is some 80 km to the south. Access to the eastern part of the area is by way of the Ontario Northland Railway line that runs from Cochrane to Moosonee. The well known site of Onakawana is a mere railway siding about 90 km south of Moosonee.

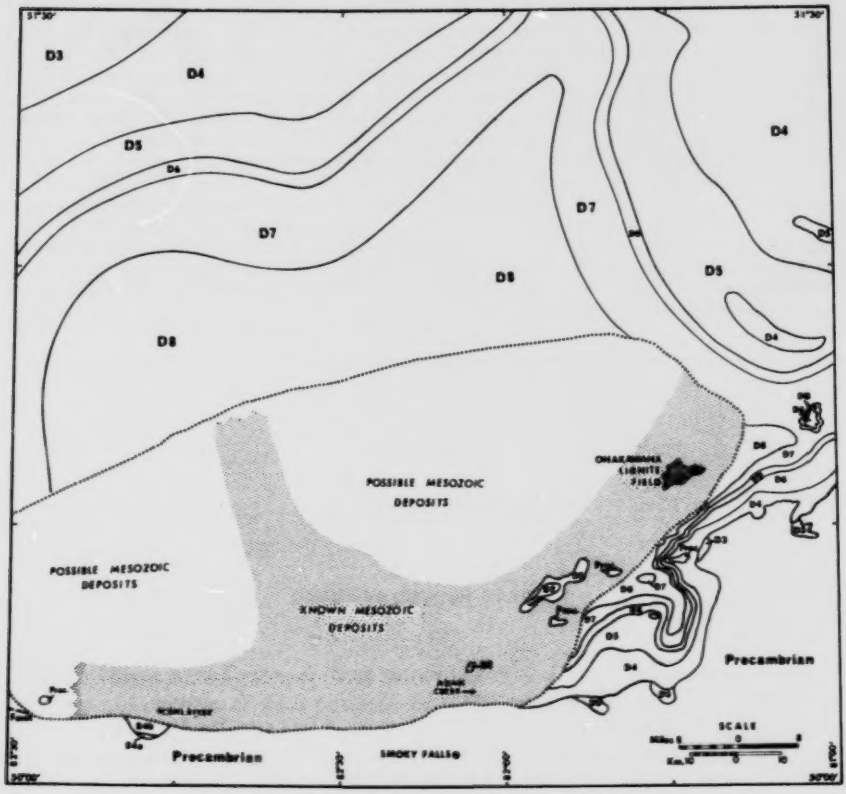

Figure 2.1–Geology of the Onakawana-Smoky Falls area.

Highway 634 leads 75 km from Highway 11 at Smooth Rock Falls to Fraserdale, and a private road continues to Smoky Falls on the Mattagami River near the southern margin of the Moose River Basin. An unpaved road extends a further 10 km north from Smoky Falls, just reaching the subcrop area of Mesozoic sediments. The Missinaibi River was recently declared a Wild River Reserve and is a popular canoe route through the region.

Because of the relative lack of access, poor bedrock exposures, and very swampy conditions of the terrain between the major rivers, ground transportation and normal field mapping methods are not feasible in the Moose River Basin. Helicopters were found to be the most convenient means of transportation, providing easy access to isolated outcrops along the rivers and allowing rapid reconnaissance of large areas. The fall 1977 drilling near Onakawana was carried out with very effective helicopter support (Verma, Telford, and Norris 1978).

OGS 10 454

Photo 2.1–Oblique Photograph, looking west-southwest, of Adam Creek where it drops from the Precambrian escarpment. A change in vegetation marks the boundary between the Precambrian and the Mesozoic sediments.

SOURCES OF DATA

As detailed in the previous chapter by H.M. Verma, the Ontario Geological Survey carried out two drilling operations, two geophysical surveys, and one outcrop reconnaissance survey in the Moose River Basin between 1975 and 1977. The results of these activities, together with subsequent laboratory analyses of the accumulated samples, form the basis of this report.

The winter 1975 drilling, involving 6 holes and total drilling depth of about 740 m, produced 1001 samples of Pleistocene, Mesozoic, and Paleozoic (Devonian) sediments (Table 2.1). All samples were cuttings produced by a reverse circulation drilling method (Rogers *et al.* 1975). Chemical, physical, and micro paleontological analyses of various types were conducted on virtually all samples (Tables 1-6 in Telford, Vos, and Norris 1975). In particular, the Mesozoic samples were examined for palynology, heavy mineral content, and clay mineralogy, and grain size analysis was carried out on the sands. Ninety samples from drillholes 75-02 and 75-06 were processed for conodonts in attempts to define more accurately the Cretaceous-Devonian boundary. An additional 25 samples of Cretaceous and Devonian material, collected during the summer 1975 outcrop reconnaissance, were subjected to the same laboratory analyses as the subsurface samples.

TABLE 2.1 | SUMMARY OF WINTER 1975 DRILLING ACTIVITIES.

Drillhole	Location	Elevation (metres)	Total Depth (metres)
75-01	85°40'51"W 50°21'43"N	92.23	45.73
75-02	82°45'46"W 50°35'27"N	149.74	130.18
75-03	82°48'08"W 50°41'35"N	163.75	134.45
75-04	82°43'03"W 50°28'00"N	119.64	165.40
75-05	82°18'38"W 50°10'05"N	100.96	87.80
75-06	82°23'13"W 50°16'58"N	93.66	174.85

The fall 1977 drilling, involving three holes and total drilling length of 147 m (Table 2.2), produced 29 split spoon samples and about 50 m of core (Appendix A in Verma *et al.* 1978). Only one of the holes penetrated definite Cretaceous sediments but extensive palynological analyses were carried out on samples from all three holes to test the lithostratigraphic correlations.

The geophysical surveys of winter 1975 (Utard 1975) and 1976 (Scintrex Surveys Limited 1976) have had only limited value in interpretation of the Mesozoic stratigraphy. Perhaps of most use was the seismic profile obtained concurrently with the winter 1975 drilling which indicated the approximate topography of the Precambrian basement and overlying Paleozoic strata.

In addition to this recently acquired data, a large body of geological information has been generated by fossil fuel and industrial mineral exploration activity in the Moose River Basin over the past 50 years. More than 400 boreholes have been drilled near Onakawana since the late 1920s, providing most detailed information on the character and distribution of Cretaceous sediments in that area. Critical information on deeper horizons has been provided by petroleum exploration holes such as the Aquitaine Sogepet Hambly No. 1 well drilled in Hambly Township (Latitude 50°15'16"N, Longitude 82°35'48"W) in 1973. The bulk of this pre-1975 data was summarized and used in the reports of Martison (1953) and Price (1978), and the history of pre-1975 geological activities in the Moose River Basin has been reviewed.

TABLE 2.2 | SUMMARY OF FALL 1977 DRILLING ACTIVITIES.

Drillhole	Location	Elevation (metres)	Total Depth (metres)
77-01	81°23′48″ 50°34′45″	51	46
77-02	81°24′42″ 50°35′09″	49	50
77-03	81°26′15″ 50°33′10″	48	51

REGIONAL GEOLOGICAL SETTING

The Moose River Basin is a southeastern extension of the large Hudson Bay Basin (Figure 2.1). The latter is centred on Hudson Bay and is mainly an offshore basin with only its southern rim constituting the mainland area. In contrast, the Moose River Basin is almost entirely an onshore basin with only a small part of its northeastern rim extending beneath the waters of James Bay. The boundary between the basins is defined by the prominent Cape Henrietta Maria Arch, a northeast trending structure marked by large areas of Archaean and Proterozoic exposures. The arch was not a complete barrier to Paleozoic sedimentation and, in places, contains a thin cover of Middle Silurian limestones and dolostones resting unconformably on the Precambrian rocks (Sanford *et al.* 1968).

The south side of the Moose River Basin, between Burstall and Kipling Townships, is defined very clearly by an escarpment of Precambrian granitic rocks. This feature, which may be fault controlled, sharply truncates the Paleozoic and Mesozoic strata of the basin. Farther to the west and northeast the Precambrian boundary is less well defined but there is still some evidence of truncation of the Paleozoic strata (Sanford and Norris 1975).

The Paleozoic sequence of the Moose River Basin has been studied on a regional scale by the Geological Survey of Canada (Sanford *et al.* 1968) and consists of an approximately 700 m of Ordovician, Silurian, and Devonian strata. These are comprised mainly of marine carbonate rocks, shales, and evaporites and minor marine and continental clastic sediments. In the southeast part of the basin the Paleozoic rocks are overlain unconformably by a sequence of unconsolidated Mesozoic nonmarine sediments which are the principal subject of this report. They are of variable thickness.

A number of Precambrian and Paleozoic inliers protrude through the Mesozoic cover and are concentrated especially in an area bounded by the Matta-

gami and Abitibi Rivers in the extreme southeast portion of the basin (Figure 1, Price 1978). One line of these inliers, trending east-west and passing through Grand Rapids on the Mattagami River, may represent a Precambrian basement ridge or younger tectonic structure, and has considerable bearing on the interpretation of Mesozoic depositional patterns. Price (1978) also used physiographic features such as the prominent deflection of the Missinaibi River immediately downstream from its confluence with the Soweska River, the clast lithology of Pleistocene sediments which blanket the entire lowlands region, and schistosity trends in Precambrian rocks east of the Moose River Basin, to support the existence of a major arch structure extending through Grand Rapids.

DISTRIBUTION AND THICKNESS OF MESOZOIC SEDIMENTS

The distribution of Mesozoic sediments in the Moose River Basin is incompletely known. Maps in Martison (1953), Sanford and Norris (1975), and Price (1978) show various interpretations but, as indicated by Price (Figure 1, 1978), large areas of supposed Mesozoic deposits are based on very poor data. Much of the geological work undertaken in the Moose River Basin has tended to be concentrated in only a few specific areas or consist only of isolated drillholes from which reliable extrapolations are difficult. The recent activities of the Ontario Geological Survey have added a considerable amount of important and useful information to the data base. Nevertheless, much more information is required before a clear understanding of the distribution of the Mesozoic sediments can be reached.

The concentration of past geological activities in particular areas, such as Onakawana, is understandable. The work was prompted by the economic potential of lignite, silica sand, and fireclay in the Mesozoic sediments and such interests were focussed logically on areas where these valuable deposits are close to surface. The Mesozoic sediments are close to surface and/or outcrop extensively in only three parts of the basin, viz Onakawana, Kipling Township, and in the vicinity of Missinaibi and Coal Rivers in McBrien and Burstall Townships. Elsewhere, the Mesozoic sediments are covered by thick sequences (up to 150 m) of Pleistocene glacial and glaciolacustrine sediments and, in the north, by marine clays of the postglacial Tyrrell Sea. As illustrated by Price (Figure 1, 1978) all known surface exposures of the Mesozoic sediments lie within 35 km of the Precambrian rocks bounding the southern and eastern margins of the Moose River Basin.

In the Onakawana area, outcrops of Mesozoic sediments (the Cretaceous Mattagami Formation) are confined to the banks of the Abitibi River. Extensive drilling operations west of the Abitibi River, that have been documented in numerous reports (e.g. Trusler *et al.* 1974), indicate a maximum thickness of about 51 m for the Mattagami Formation. Two lignite fields, known as the Main and East Fields, have been defined in this area.

The fall 1977 drilling by the Ontario Geological Survey (Verma, Telford and Norris 1978) revealed a 17 m thickness of the Mattagami Formation east of the Abitibi River (Figure 2.2), though the distribution of Mesozoic sediments is

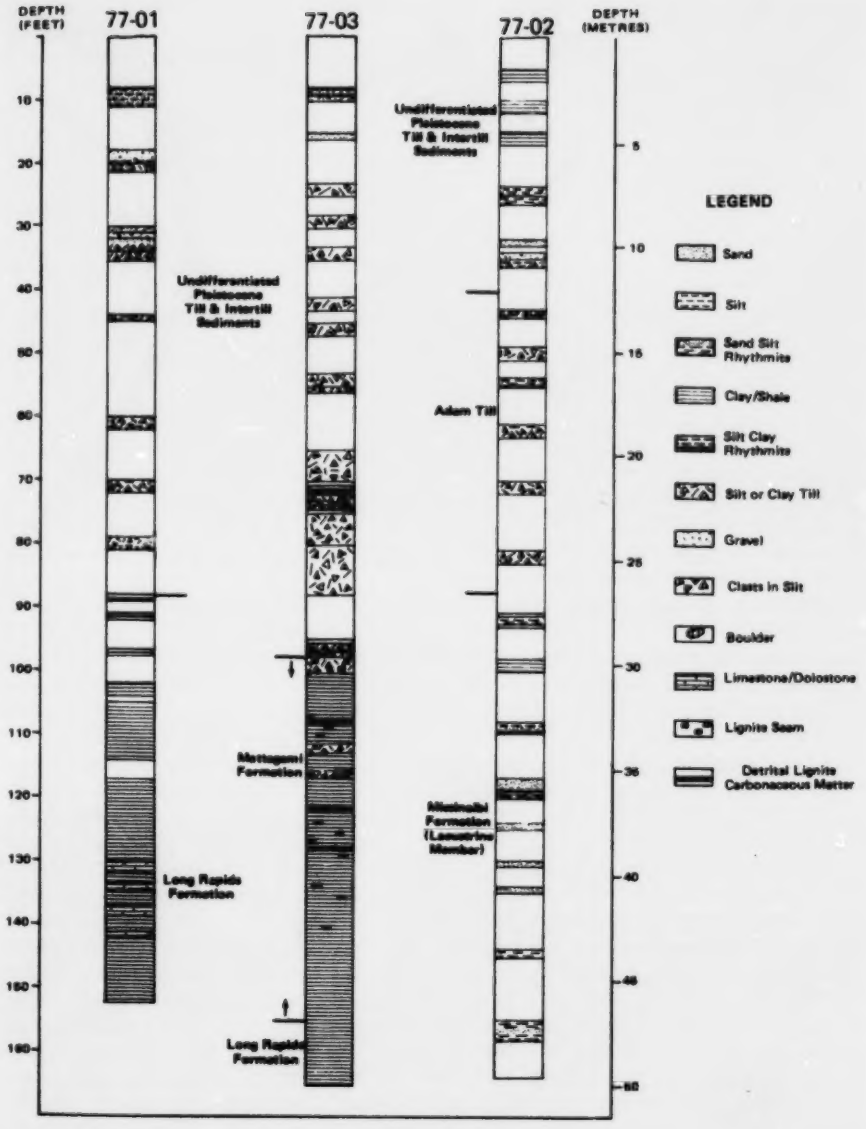

Figure 2.2–Diagram showing drillhole logs of holes 77-01, 77-02, and 77-03, east of Abitibi River, near Onakawana.

quite irregular in this area and appears to be controlled by structural highs in the underlying Devonian bedrock. North of Onakawana, Mesozoic sediments have been encountered in the subsurface near Portage Island, immediately downstream from the confluence of the Missinaibi and Mattagami Rivers. A small lignite field, known as the Portage field, has been defined at this location. Many geological maps of the Moose River Basin (e.g.Sanford *et al.* 1968; Rogers *et al.* 1975) show Cretaceous sediments extending as far north as the Kwataboahegan River. However, at the present time, no definite surface or subsurface occurrences of Mesozoic sediments have been recorded northwest of the Onakawana and Portage Island area.

Sporadic drilling between Onakawana and Kipling Township, 60 km to the southwest, suggests that the Mesozoic sedimentary cover is more or less continuous between these regions. An exception is the Grand Rapids area where previously mentioned Paleozoic and Precambrian inliers are covered only by Pleistocene sediments.

Abundant outcrops of quartz sands and carbonaceous clays of the Mattagami Formation occur along the Mattagami River and Adam Creek in Kipling Township (Telford *et al.* 1975; Norris *et al.* 1976). Adam Creek is used as a diversion channel for Ontario Hydro dams on the nearby Mattagami River. Since 1966, when this diversion channel was created, severe and rapid erosion of the stream banks has produced excellent exposures of Pleistocene, Cretaceous, and Devonian strata (Photos 2.2 and 2.5). The total thickness of the Cretaceous sediments cannot be estimated from the surface exposures. However, Ontario Geological Survey drillhole 75-05 (Figure 2.7), situated on Waboose River in Acres Township, only about 15 km west of the Mattagami River, penetrated about a 53 m thickness of Cretaceous sediments.

Farther north in McCausland Township, Ontario Geological Survey drillhole 75-06 (Figure 2.8) revealed a complete Cretaceous section of about 86 m thickness. The Aquitaine-Sogepet Hambly No. 1 petroleum exploration hole in Hambly Township found a similar thickness of Mesozoic (probably Cretaceous) sediments. Between Hambly and McBrien Townships no surface or subsurface occurrences of Mesozoic sediments are known, but it seems most probable that Mesozoic deposits are continuous along this southern margin of the Moose River Basin. Drilling in Garden and Wright Townships during the fall of 1978 by the Ontario Geological Survey has confirmed the presence of Mesozoic sediments in this extreme southern part of the basin (Telford and Verma 1978).

As summarized by Price (1978), there have been numerous reports of Mesozoic sediments in the vicinity of Missinaibi and Coal Rivers (McBrien and Burstall Townships), both in riverbank exposures and shallow drillholes. Many of the outcrops described by early workers (Keele 1920; McLearn 1927) cannot be examined at present as they have been obscured by erosion and slumpage of the riverbanks. However there is little doubt that Mesozoic sediments are present at relatively shallow depths throughout this area. Between 1965 and 1970, Algocen Mines Limited carried out an extensive drilling and sampling programme in the northeast part of McBrien Township and located considerable thicknesses of Mesozoic (probably Cretaceous) quartz sands and kaolinitic clays (Vos 1975). Algocen found a maximum thickness of 51 m of the sands and clays although this did not represent a total thickness of the Mesozoic unit as Paleozoic bedrock was not reached by the drilling (Smith and Murthy 1970).

OGS 10 455

Photo 2.2–Photograph showing outcrop of Sextant Formation (at water level) east bank of Adam Creek, about 3 km from its mouth.

West of the Burstall-McBrien Township region there are no known occurrences of Mesozoic sediments, so the extent of Mesozoic deposition in this direction and boundaries shown on many published geological maps of this area are most uncertain. However, considering the thickness of probable Cretaceous sands and clays on the Algocen property, it is likely that Mesozoic sediments do extend some distance west of Burstall Township.

Northwards, toward the central part of the Moose River Basin, data pertaining to the Mesozoic sediments are also meagre. Price (1978) noted several small outcrops of possible Cretaceous sands along the Missinaibi River in Habel Township. This area was visited during the summer of 1975 and two sections, both less than 1 m in thickness, were found to contain possible Mesozoic sediments. Site A (Photo 2.4), situated on the north side of the Missinaibi River about 1 km downstream from the mouth of the Soweska River, contains nonlithified, coarse grained, red, ferruginous, quartz sand. Site B (Photo 2.3), situated on the south side of the Missinaibi River, about 10 km upstream from the mouth of the Opasatika River, contains white quartz sand overlying red plastic clay. Unfortunately, samples from these sites were too oxidized to allow a palynological age determination.

OGS 10 456

Photo 2.3–Photograph showing an outcrop of Mattagami Formation at Site B, south side of the Missinaibi River, about 10 km upstream from the mouth of the Opawatika River.

The only other data on the Mesozoic sediments of the central part of the Moose River Basin are Ontario Geological Survey drillholes 75-01 to 75-04 (Figure 2.2). These holes were drilled at 12-15 km intervals on an approximate north-south line between the Missinaibi and Rabbit Rivers (Figure 1.3). They revealed varying thicknesses of Mesozoic sediments (maximum 25 m) and, as determined palynologically (Telford *et al.* 1975; Norris 1977), both Middle Jurassic and Lower Cretaceous ages. A detailed discussion of these important discoveries is given later in this chapter and in a following chapter by G. Norris.

OGS 10 457

Photo 2.4–Photograph showing non-lithified, coarse, ferruginous sands of the Mattagami Formation at Site A, north bank of the Missinaibi River, about 1 km downstream from the mouth fo the Soweska River.

The main points to be emphasized at this stage are:

1. the Mesozoic sediments decrease in thickness to the north, i.e. away from the margin of the Moose River Basin,
2. the northernmost confirmed occurrence of Mesozoic sediments is Ontario Geological Survey drillhole 75-03 near Rabbit River,
3. no other evidence is available for areas east, west, and north of the winter 1975 drillholes.

OGS 10 458

Photo 2.5–Photograph showing outcrop of Mattagami Formation in contact with the overlying Quaternary deposits exposed on Adam Creek.

MISTUSKWIA BEDS

Two of the winter 1975 drillholes (75-02, 75-03) encountered nonlithified sands and clays that appeared lithologically different from sediments of the Mattagami Formation found elsewhere in the basin. Palynological analysis (Norris 1977; this report) established a Middle Jurassic age for the clay horizons, and Hamblin (1976; this report) confirmed the distinct lithological nature of the sands. Lack of data prevents definition of precise geographic and stratigraphic boundaries for this new rock unit so that it cannot be accorded full formational status. Following Telford *et al.* (1975), the informal name Mistuskwia Beds is applied. The beds are named after the Mistuskwia River, a tributary of the Kwataboahegan River in the central part of the Moose River Basin.

Detailed descriptions of the occurrences of the unit in the two drillholes are provided below, and in the following chapter by A.P. Hamblin. Briefly, the Mistuskwia Beds consist of varicoloured (grey, green, brown, pink and red), calcareous clays and thinner horizons of nonlithified, grey to white, fine to medium grained, calcareous quartz sands.

Drillhole 75-02

Petrographic studies by Hamblin (1976; this report) have established the occurrence of the Mistuskwia Beds at a depth of 107.7 m to 125.8 m in this drillhole (Figure 2.3). This was confirmed by Price (1978) after examination of the Ontario Geological Survey material.

From 107.7 m to 114.2 m the sequence consists of greenish-grey, grey-brown,and light brown, calcareous clay with occasional thin laminae of white kaolinitic clay. Between 114.2 m and 121.2 m the dominant lithology is a white, medium to fine grained, calcareous, quartz sand with minor green clay laminae. From 121.2 m to 123.7 m the sands are much coarser grained, and the basal 2.0 m of the Mistuskwia Beds is a conglomerate with abundant limestone fragments, small pyrite concretions, reddish sandstone fragments, and quartz, chert, and volcanic pebbles in a sandy silt matrix.

Overlying the Mistuskwia Beds in this drillhole is an 8.4 m interval of grey, medium to coarse grained, quartz sand interbedded with grey and brown clay and sandy clay. Lower Cretaceous palynomorphs were extracted from clay samples in the upper part of the interval (Telford *et al.* 1975). The boundary between these probable Lower Cretaceous sediments and the Mistuskwia Beds is quite sharp. The lower boundary of the unit is also sharp with the nonlithified Middle Jurassic sediments underlain by brown and buff, argillaceous limestone that is probably referable to the Middle Devonian Williams Island Formation.

Drillhole 75-03

This northernmost drillhole (Figure 1.3) displays an incomplete section of the Mistuskwia Beds extending from 116.3 m to the bottom of the hole at 135.7 m depth (Figure 2.4). Middle Jurassic palynomorphs were identified by Norris (1977) from samples between 119.1 m and 128.6 m. Using parameters such as sorting, roundness, and sphericity, Hamblin (1976; this report) confirmed that grey quartz sands occurring between 116.3 m and 119.1 m were distinctly different from sands of the Mattagami Formation.

The lithologies of the Middle Jurassic sediments in this drillhole are very similar to those of drillhole 75-02. Clays, which make up most of the section are varicoloured and calcareous. Quartz sands, which are interbedded with the clays in the upper 8.0 m of the section, are grey or light brown, medium to fine grained, well sorted and rounded, and calcareous. The upper boundary of the Mistuskwia Beds with overlying Pleistocene gravel is sharp although, as noted

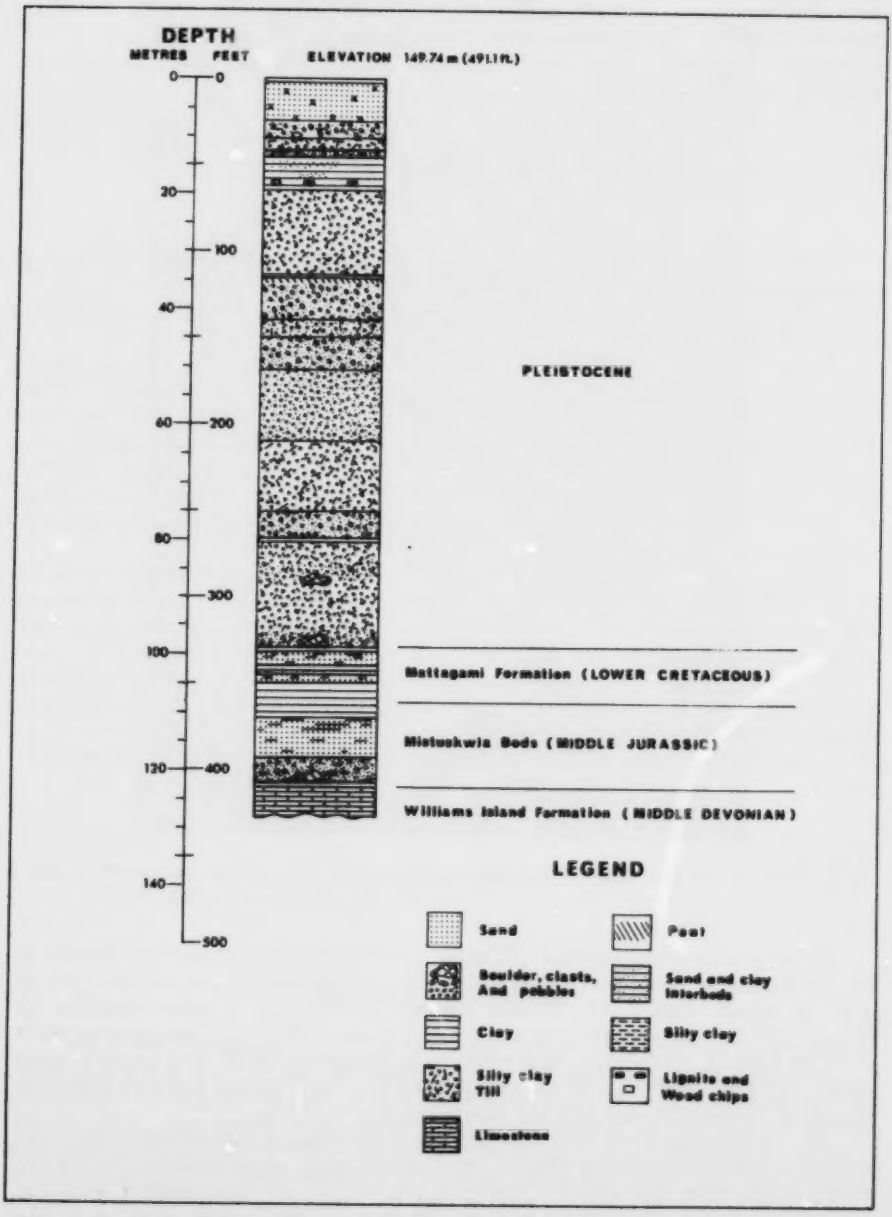

Figure 2.3–Diagram illustrating log of Drillhole 75-02.

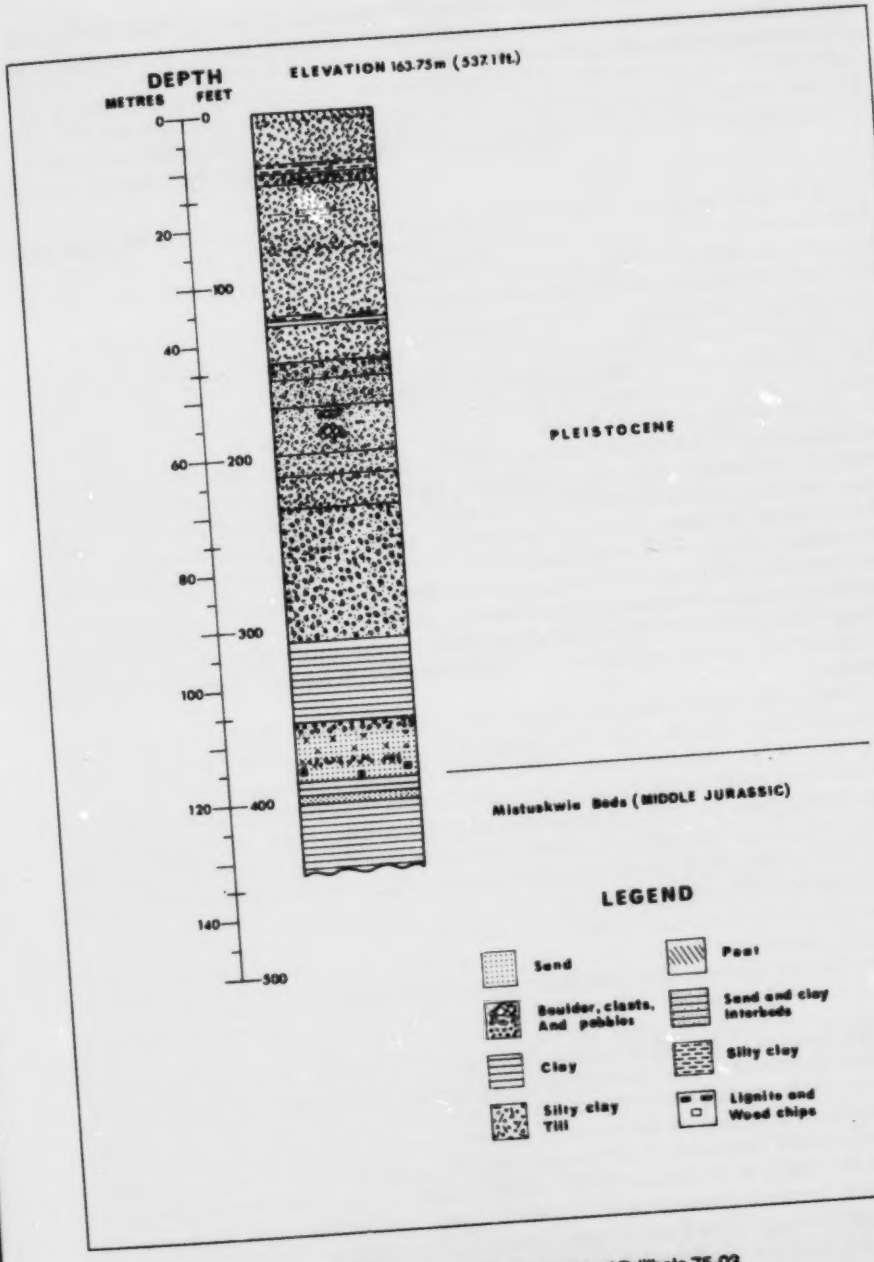

Figure 2.4–Diagram illustrating log of Drillhole 75-03.

by Hamblin (this report), abundant lignite detritus in one sample at 116.3 m may indicate a minor Cretaceous erosional residue between the Pleistocene and the Middle Jurassic sediments.

Age and Correlation

A detailed account of the palynologically determined age of the Mistuskwia Beds is provided by Norris (1977; this report). The unit is Middle Jurassic in age and correlative with the Upper Gravelbourg, Sawtooth and Shaunavon Formations of southern Alberta and Saskatchewan.

MATTAGAMI FORMATION

Keele (1920) proposed the name Mattagami series for nonlithified, lignite bearing sands and clays overlying Upper Devonian strata along the Mattagami River in the general vicinity of Onakawana. He was followed by Dyer (1928) who designated these Mesozoic sediments as the Mattagami Formation. No type section of the unit was proposed then, or has been proposed in any subsequent studies, and no single exposure of the entire Mattagami Formation is known. As noted previously, numerous drillholes in the Onakawana and Smoky Falls-Hambly Township area have provided complete sections of the formation and it may be useful to designate one or more of these as reference sections.

Two of the better documented recent drillholes that could serve as reference sections are the Hambly No. 1 hole (Figure 2.9), drilled by Aquitaine Sogepet *et al.* (1973), and drillhole 75-06 of the Ontario Geological Survey winter 1975 drilling programme (Figure 2.8). Both holes intersected complete sections of the Mattagami Formation and encountered a combination of lithologies that is very typical of the unit. An added feature of the Hambly No. 1 hole was the down-hole geophysical logging (gamma-ray; neutron activation) carried out concurrently with the drilling.

Distribution and Thickness

Distribution of the Mattagami Formation in the Moose River Basin was discussed previously. The lateral extent of the unit cannot be defined precisely. However, it is thought to extend, virtually continuously, around the eastern and southern margins of the basin from the Portage Island area in the northeast to Burstall Township in the southwest. The winter 1975 drilling found the unit as far north as drillhole 75-02, about 50 km north of the Precambrian escarpment. Surface exposures of the Mattagami Formation occur in the northeast near Portage Island and Onakawana, in the southeast along Adam Creek (Photo 2.5) and the Mattagami River in Kipling Township, and along the Missi-

naibi River in Burstall, McBrien, and Habel Townships (Photos 2.3 and 2.4).

Thickness of the formation varies greatly. In the intensively drilled Onakawana area the maximum known thickness is 51 m. However, the Hambly No. 1 hole contained a 121.4 m section (Figure 2.9) and in drillhole 75-06 (Figure 2.8) the unit was about 86 m in thickness. Only 8.4 m of the formation was present in drillhole 75-02 (Figure 2.3) which is believed to be close to the northern erosional edge of the unit.

Lithology

A comprehensive account of all lithologies comprising the Mattagami Formation in its outcrop areas and various subsurface locations was provided by Price (1978). Therefore, descriptions in this paper are confined mainly to the new data obtained from the winter 1975 and fall 1977 drillholes. Many detailed descriptions of individual sand and clay samples from holes 75-01 to 75-06 are contained in the following papers by Hamblin and Vos. Briefly, the Mattagami Formation consists of an extremely variable sequence of nonlithified varicoloured clays and silts, white quartz sands, and occasional seams of lignite. Two sediment associations appear to be present, one typified by dark grey or black clay and silt commonly associated with abundant detrital or *in situ* carbonaceous material, and the other characterized by thick sections of interbedded sand, oxidized reddish to light brown clays, and white kaolinitic clays. In the following lithological descriptions these sediment associations are referred to as Type A and Type B respectively.

DRILLHOLE 75-01

This drillhole (Figure 2.5) contained an incomplete 33 m section of the Mattagami Formation beginning at a depth of 12.8 m. Sediments were of the Type B association, consisting of white, fine to coarse grained, pure quartz sands interbedded with thin horizons of white, red, yellow and light brown kaolinitic clay. The upper boundary of the Mesozoic sediments was relatively sharp; basal Pleistocene deposits consisted of a coarse gravel bed overlain by sandy clay till. The Mattagami Formation section of this drillhole corresponds closely to the upper 63 m of the Mesozoic section in the Hambly No. 1 hole, drilled about 11.5 km to the south. The 66 to 129 m interval of the latter drillhole was logged as white, medium to coarse grained, angular, fluviatile quartz sand with 4 feet to 10 feet clay layers (Aquitaine Sogepet *et al.* 1973).

DRILLHOLE 75-02

Sediments that are possibly referable to the Type B association of the Mattagami Formation occurred between 99.1 and 107.5 m in this drillhole (Figure

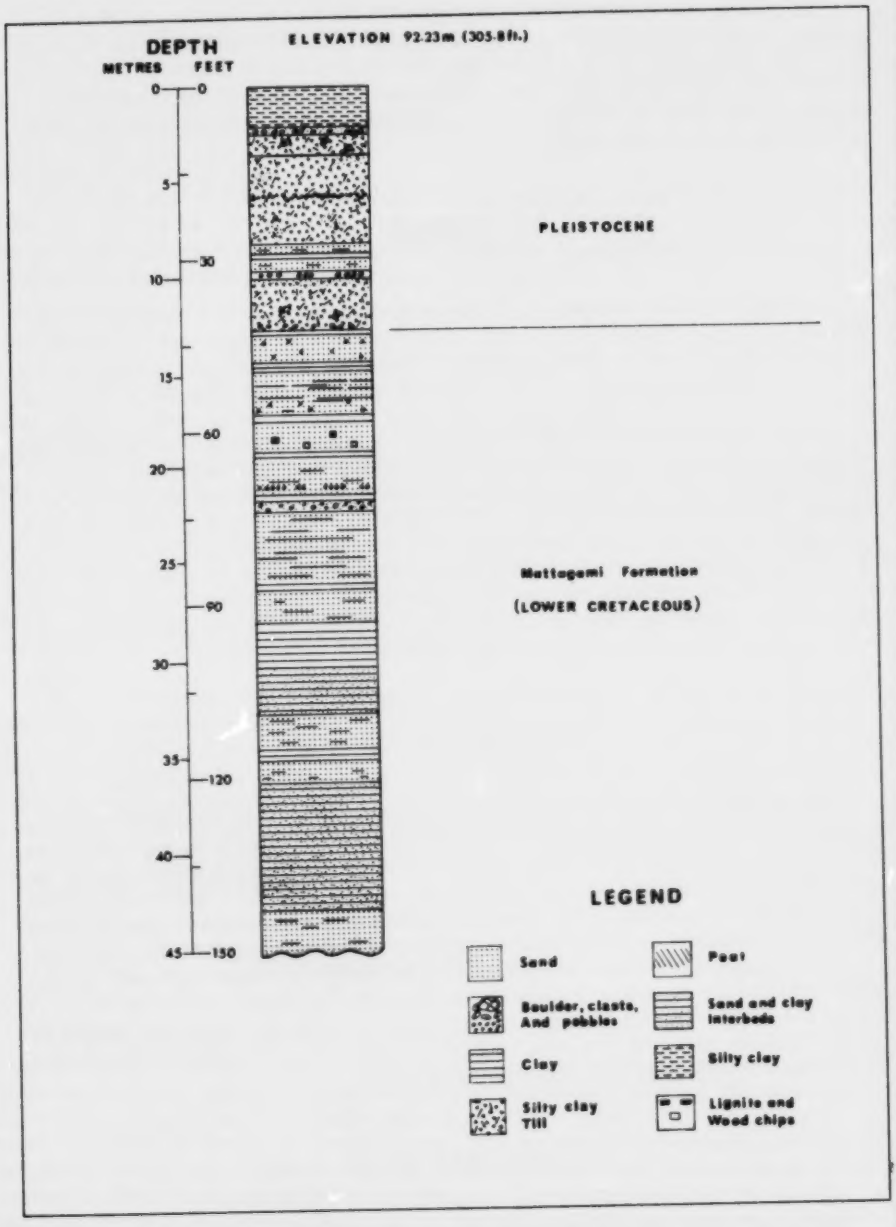

Figure 2.5–Diagram illustrating log of Drillhole 75-01.

2.3). Their lithology and contact relationships with the underlying Middle Jurassic Mistuskwia Beds were noted previously. The upper boundary of the Mattagami sediments was sharp and, as in drillhole 75-01, was marked by a Pleistocene gravel bed overlain by sandy clay till.

DRILLHOLE 75-04

This drillhole (Figure 2.6) contained an incomplete 14.5 m section of the Mattagami Formation beginning at a depth of 152.4 m. These sediments are possibly referable to the Type A association, consisting of impure, fine- to coarse-grained quartz sand and thin horizons of grey and greenish-grey clay. The upper boundary of the unit with overlying Pleistocene deposits is difficult to place and may be gradational. The lower Pleistocene deposits in the drillhole, between 150 m and 152 m, are mainly grey, varved clay with minor silty laminations while the uppermost Mesozoic sediments are grey clay also. However, the Pleistocene-Mesozoic boundary could be represented at 152 m by a sandy gravel bed with peat fragments.

DRILLHOLE 75-05

This drillhole (Figure 2.7) contained an incomplete 66 m section of the Mattagami Formation, beginning at 22.8 m depth. It is one of the thickest sections known of the formation. Type B sediments occurred between 22.8 m and 32.3 m, consisting of interbedded orange to reddish brown clay and medium to coarse grained, pure quartz sand. Varicoloured clays and silts, between 32.3 m and 47.7 m, are probably referable to the Type A sediment association and included brown, olive green, light and dark grey, and black varieties. The remaining 40 m of section in the drillhole contained sediments again referable to the Type B association. Very pure, fine- to coarse-grained, weakly calcareous, quartz sands with occasional 1 to 3 m zones of white, yellow, and red kaolinitic clay were present. The upper boundary of the Mattagami Formation was sharply defined; the basal 0.5 m of Pleistocene deposits consisted of pebbly gravel in a sandy matrix.

DRILLHOLE 75-06

The thickest and most complete section of the Mattagami Formation encountered in the 1975 programme was present in this drillhole (Figure 2.8). As described in the following chapter by A.P. Hamblin, two depositional phases of the Mattagami Formation could be delineated in this section. From 51.2 m to about 72.0 m the Mesozoic sediments consisted of grey clay and silt with occasional horizons of very fine quartz sand. The following 22.0 m of section was dominated by white, fine to coarse grained, very pure, well sorted, poorly calcareous, quartz sand with laminae and/or matrix of white kaolinitic clay. All of

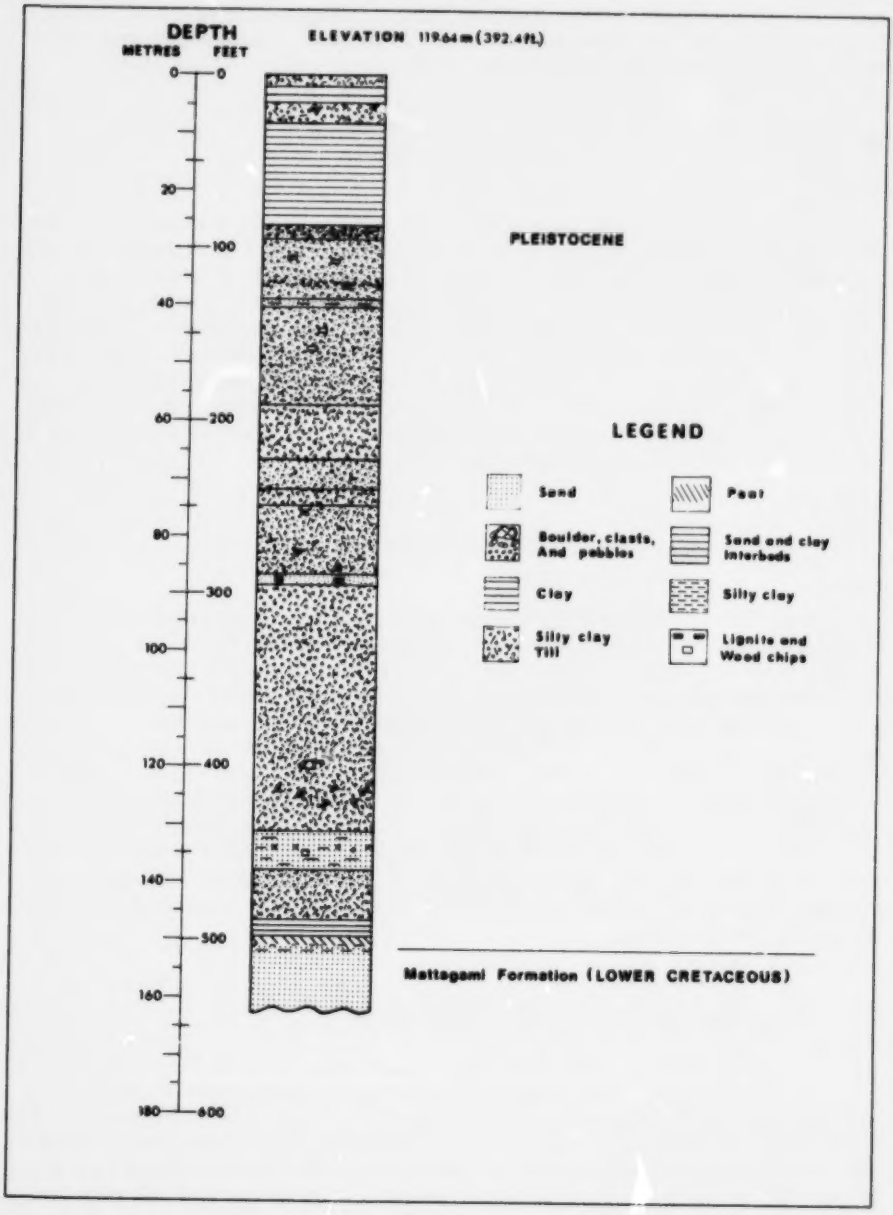

Figure 2.6–Diagram illustrating log of Drillhole 75-04.

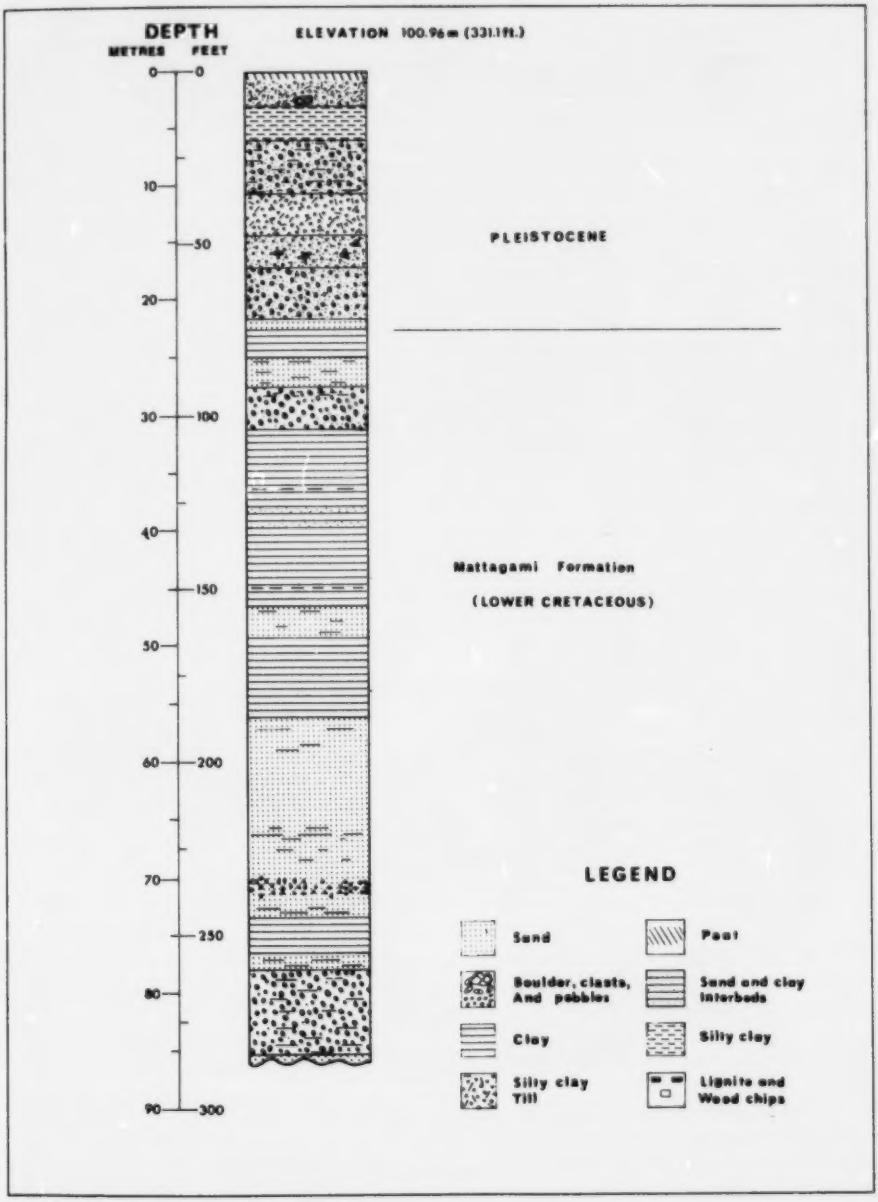

Figure 2.7–Diagram illustrating log of Drillhole 75-05.

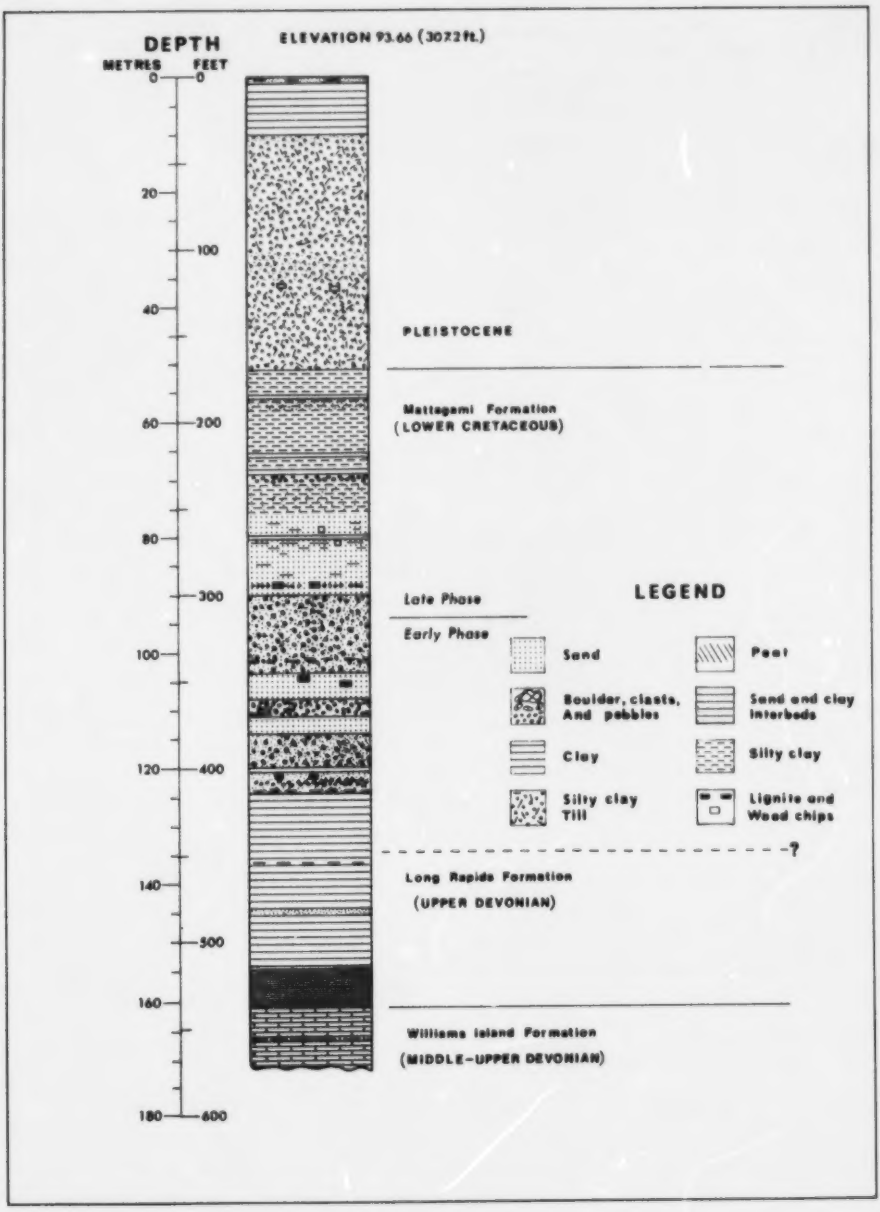

Figure 2.8–Diagram illustrating log of Drillhole 75-06.

these sediments are possibly referrable to the Type B association and represent the younger phase of Mattagami deposition.

As detailed by Hamblin (this report), quartz sands below 93.8 m, to a depth of about 128.0 m, were strongly calcareous and had higher grain size and sphericity than the overlying sands. In addition, at depths of 90.5 m, 104.0 m, 107.0 to 109.0 m, 110.8 m, and 124.3 m, the sands contained abundant detrital lignite fragments. Underlying the sands to a depth of 137.1 m, were brownish grey, dark grey, and black clays with finely disseminated carbonaceous materials. These clays and immediately overlying calcareous quartz sands are referable to the Type A sediment association and were interpreted by Hamblin to represent an older phase of Mattagami deposition.

The upper boundary of the Mattagami Formation in this drillhole was sharply defined with stratified silts and clays abruptly overlain by massive clayey silt till. The lower boundary with the Upper Devonian Long Rapids Formation is more difficult to place. The Devonian unit has undergone deep, pre-Cretaceous weathering so that, in the upper part, the original fissile shales appear similar to the overlying Cretaceous clays. The latter are probably comprised partly of reworked material from the Long Rapids Formation. Cretaceous palynomorphs have been found to a depth of 135.7 m (Telford *et al.* 1975; Norris this report). Upper Devonian conodonts were found as high as 150.8 m. The intervening 15.1 m, which was analyzed for but barren of both palynomophs and unreworked conodonts, contained a mixture of grey and olive-green clay. A tentative boundary was placed at 137.1 m where a thin, oxidized, reddish brown clay horizon may represent a former erosional surface.

DRILLHOLE 77-03

One drillhole of the fall 1977 programme near Onakawana (Verma *et al.* 1978) encountered a section (approximately 17 m thick) of the Mattagami Formation. From 29 m to 46 m depth in this hole the sediments consisted of a mixture of highly disturbed and contorted, noncalcareous, soft, greenish grey, plastic clay and hard, dark brown to black, crumbly, dense clay. In some samples the greenish clays contained inclusions of brown clay and displayed numerous shear planes. Finely disseminated and occasional euhedral pyrite crystals were also present. Lignite occurred in the form of detrital fragments as well as thin (5 cm to 8 cm) seams. The sediments could be referred to the Type A association, and lacked the quartz sands that were so typical of the Mattagami Formation in the 1975 drillholes.

Upper and lower contacts of the Mattagami Formation in drillhole 77-03 were not well defined. The upper boundary was marked by a 7 m thick transition zone containing a mixture of silt and clay tills, soft contorted dark brown to black and greenish grey clays, and lignite detritus. The lower boundary was defined by a 2 m thick transition zone comprised of hard, dark brown, fissile shales and soft, greenish grey clays. The Upper Devonian Long Rapids Formation underlies the Mattagami Formation at Onakawana. As noted previously, the boundary between these units is not clearly marked because of the similarity of the clays and weathered shales of the two formations, as well as the fact that

sediments of the lower part of the Mattagami Formation were probably derived from the Long Rapids Formation.

Palynological analysis of samples from drillhole 77-03 (Verma, Telford and Norris 1978) suggested a more restricted interval for the Mattagami Formation. Only Devonian palynomorphs were found below 39.6 m and the highest Cretaceous palynomorphs occurred at 32.9 m.

Age and Correlation

Bell (1928) published a description of macroplant remains from the Mattagami Formation that suggested a Cretaceous or possibly Late Jurassic age for the unit. Recent palynological studies reported by Telford *et al.* (1975), Norris *et al.* (1976), and Verma *et al.* (1978) have provided considerable refinement of the early age determination. A detailed synthesis of the palynological work is provided by Norris (this report). The Mattagami Formation ranges from Middle to Upper Albian (Lower Cretaceous) in age and is correlative, in particular, with the Loon River, Peace River, and lower Shaftesbury Formations of northwest Alberta and the Swan River and Ashville (in part) Groups of Manitoba and Saskatchewan.

STRATIGRAPHIC RELATIONSHIPS

Identification of precise stratigraphic or geographic boundaries for the Mesozoic units of the Moose River Basin is difficult, as the sediments mainly occur in discontinuous lenses of small areal extent. However, some general observations on stratigraphic relationships can be attempted in the light of recent studies. These have shown that essentially three Mesozoic stratigraphic or depositional units are involved, viz Middle Jurassic Mistuskwia Beds and early and late phases of the Lower Cretaceous Mattagami Formation.

The configuration of the Precambrian and/or Paleozoic "basement" has exerted considerable influence on the development of the Mesozoic units. The southern margin of the Moose River Basin is marked by a prominent, fault controlled, Precambrian escarpment. This feature has had a two-fold effect, in limiting the southern extent of Paleozoic and Mesozoic deposition, as well as providing an upland source of terrigenous detritus. As postulated by Price (1978), a ridge of Precambrian rocks may also be present in the central part of the basin, extending east-west through the Grand Rapids area. Seismic results from the Ontario Geological Survey winter 1975 programme (Utard 1975) confirmed the existence of this ridge (probably equivalent to Grand Rapids Arch) but showed it to be a broad shallow structure with only about 80 m of relief. However, the 1975 seismic work also suggested the presence of two Paleozoic ridges, in the vicinity of drillholes 75-01 and 75-02, corresponding approximately to the Precambrian structure (Figure 2.9). The occurrence of two narrow Paleozoic ridges rather than a single broad ridge could be the result of the deep post-Paleozoic erosion that has produced a trough-like structure in the

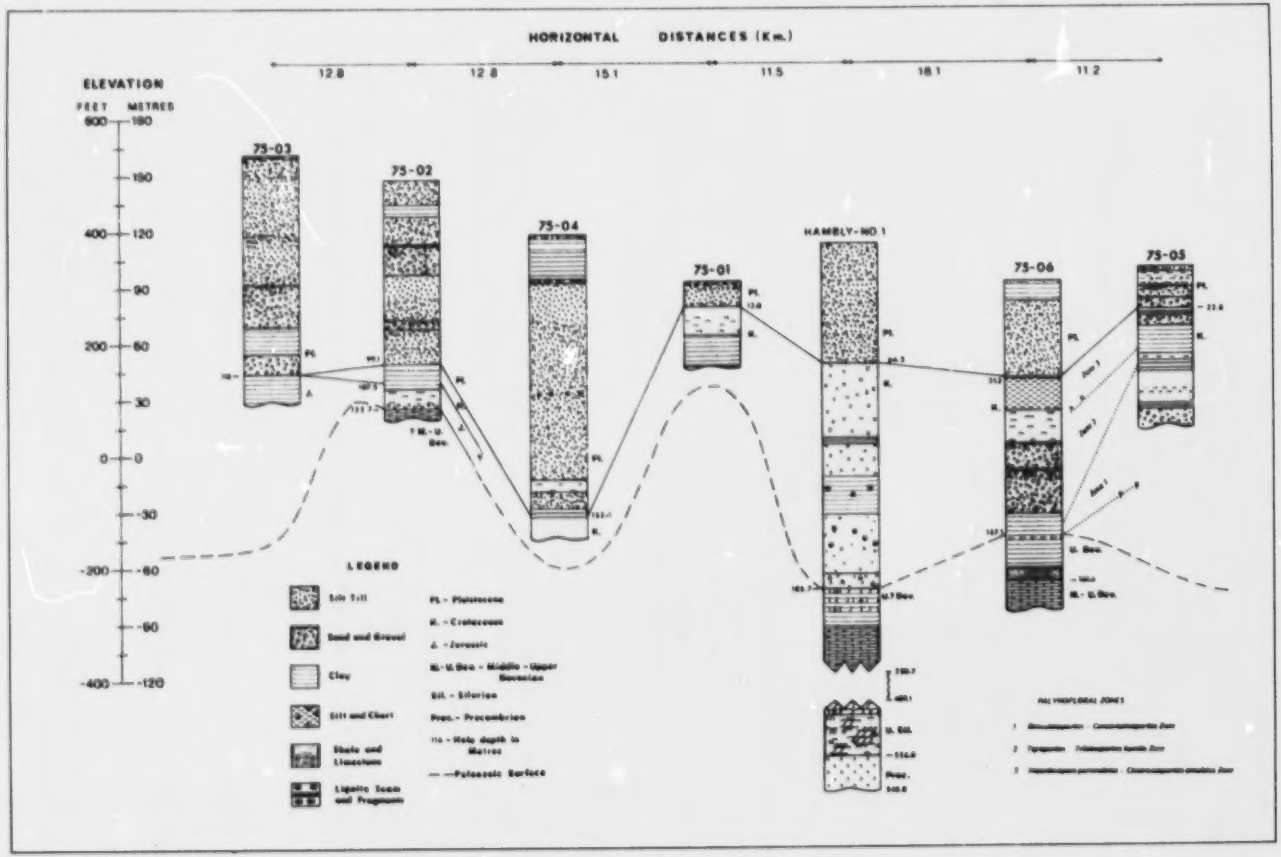

Figure 2.9–Correlation of Drillholes 75-01 to 75-06.

vicinity of drillhole 75-04.

The Mistuskwia Beds appear to be restricted to the central part of the Moose River Basin and extend no farther south than the Grand Rapids Arch complex. Hamblin (this report) suggests a provenance in the northwest for the Middle Jurassic sediments, i.e. a gross direction of transport from northwest to southeast with passage finally halted by the Grand Rapids Arch.

The early phase of deposition of the Lower Cretaceous Mattagami Formation, identified in drillhole 75-06, was restricted to the marginal areas of the Moose River Basin, and the terrigenous sediments were derived from the southern Precambrian uplands. Compared to the later depositional episodes, the early phase was comparatively weak and extended no farther north than the Grand Rapids Arch. The calcareous sands and clays accumulated in a narrow east-west trough lying between the Precambrian escarpment and the Grand Rapids Arch. This restricted depositional environment was conducive to lignite accumulation, as evidenced by abundant detrital lignite found in drillhole 75-06. The clays and lignites of the Mattagami Formation in the Onakawana area have been shown palynologically, to correlate with the early depositional phase. As this area lies north of the Grand Rapids Arch, it is probable that the deposition at Onakawana took place in a separate sub-basin.

The later phase of deposition of the Mattagami Formation was a stronger and more widespread event. As in the early phase, the sediments were derived from the southern Precambrian uplands. However, there may have been renewed uplift of this region which resulted in increased erosional activity, and a substantially greater supply of sediments to the Moose River Basin. The sands and clays of the upper Mattagami Formation extended over the former barrier of the Grand Rapids Arch and partly overlapped the older Mistuskwia Beds (Figure 2.8).

More precise stratigraphic relationships between the Mattagami Formation and underlying Mistuskwia Beds remain uncertain. The Mattagami Formation is certainly thinning northwards and only just overlaps the Jurassic unit before pinching out. The Grand Rapids Arch, while not forming a complete barrier to transportation, retained some control over distribution of the Cretaceous sediments. The palynologically defined hiatus between the Mistuskwia Beds and Mattagami Formation may have considerable significance as a similar disconformity between Middle Jurassic and Lower Cretaceous clastic sediments has also been identified in the subsurface of southeastern Saskatchewan (Playford 1977). An epeirogenic event of continental proportions is indicated.

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Petrography of Mesozoic and Pleistocene Sands in the Moose River Basin

by

A.P. Hamblin[1]

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[1]Amoco Canada Limited, Calgary.

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ABSTRACT

Study of Mesozoic and Pleistocene sands from drillholes in the James Bay Lowland indicates that their petrography may be used to differentiate four sedimentary units. Properties of colour, sorting, roundness, sphericity, purity, grain size, clay, organic and carbonate contents, granule lithology, calcite-dolomite ratios and heavy mineral assemblages are important. The Middle Jurassic Mistuskwia Beds consist of grey, calcareous, sorted, rounded, spherical, fine to medium, pure quartz sand without organics and may be second-cycle sediments. Lower Cretaceous Mattagami Formation sands are divided into older, white, calcareous, sorted, angular, spherical, medium, pure quartz sand with abundant lignite fragments and authigenic pyrite, and younger, white, sorted, angular non-spherical, fine, very pure quartz sand with abundant kaolin. Pleistocene sand is characterized as calcareous, unsorted, angular and impure, with little matrix, no organics and variable granule lithology. Heavy mineral suites for these units have been determined, and an inverse relation between blue-green hornblende and authigenic pyrite was identified.

INTRODUCTION

Stratigraphically useful criteria were sought to distinguish unlithified Pleistocene, Lower Cretaceous, and Middle Jurassic sands known to occur in the subsurface of the Moose River Basin. Various parameters of sedimentary petrography, including heavy mineral analyses, carbonate analyses, and grain descriptions were used and additional details were determined in the petrography and extent of the Mattagami Formation, and the newly-defined Mistuskwia Beds (Telford *et al.* 1975; Telford, this report).

In a drillhole, if Cretaceous sands are overlain by Pleistocene sands rather than till, the two may be difficult to distinguish. For many years the Mattagami Formation was included in the Pleistocene, until Bell (1928) demonstrated by paleobotany that sediments of Mesozoic age were present. The Mattagami Formation and Mistuskwia Beds also have similar lithologies and placing contacts has been tentative. The only fossils contained in these Mesozoic deposits are a few lignitized twigs and branches, and palynomorphs requiring extensive specialized study. The unconformity between Pleistocene and Cretaceous sequences spans probably 100 million years while that between the Lower Cretaceous and Middle Jurassic is about 60 million years and both are accompanied by palynological "gaps". The objective of this study was to establish petrographical "gaps" at the contacts, if they exist, and define criteria to differentiate the units in field examination.

Sand samples taken from four of six Ontario Geological Survey winter 1975 drillholes consisted of the finer fraction of interval samples from selected arenaceous segments of drillholes 75-02, 75-03, 75-05, and 75-06 (Table 3.1).

Five days of helicopter-supported field work allowed examination and sampling of a few Cretaceous outcrops in the southern Moose River Basin, includ-

TABLE 3.1 | SAND SAMPLE INTERVALS, AND CORRESPONDING DEPTHS OF DRILL-HOLES, USED IN THIS STUDY. LOCATION OF DRILLHOLES SHOWN IN FIGURE 1.3.

Hole	Sampled Interval (sample numbers)	Depth (metres)	Elevation (metres)
75-02	125-153	94-106	55-43
	166-176	113-125	37-25
75-03	165-178	112-119	37-31
	185-189	121-123	28-26
75-05	26-39	20-29	81-72
	78-102	60-84	42-17
75-06	57-138	47-126	46-31

ing recent exposure of the Pleistocene-Cretaceous contact on Adam Creek (50°10′N, 82°07′W) (Figure 3.1) and a small bank exposure on the Missinaibi River (50°22′N, 82°32′W) (Figure 3.1).

Heavy mineral separations of samples from drillholes 75-02 and 75-06 of the -60 + 120 mesh (2Z8 to 3Z8) fraction were obtained using tetrabromethane (S.G. = 2.95). These separates were mounted semipermanently in Aroclor number 4465 (n = 1.664 to 1.667), identified and described with a petrographic microscope. Three hundred grains were point-counted and identified from each slide and the values converted to percentages for each mineral species for the 59 samples. Whole sand samples from all four holes and field work were also examined and described with a binocular microscope and finally, a detailed carbonate analysis of all samples was done using Chittick apparatus as described by Dreimanis (1962). All data is listed in the accompanying appendices.

PETROGRAPHY OF THE SANDS

Outcrop Samples

Several sand outcrops in the southern part of the basin were sampled and described. A recent exposure of the Pleistocene-Cretaceous contact on Adam Creek revealed the section shown in Figure 3.1. Another bank outcrop at water level on the Missinaibi River underlain by a small amount of bright red clay and assumed to be Cretaceous is also illustrated in Figure 3.1.

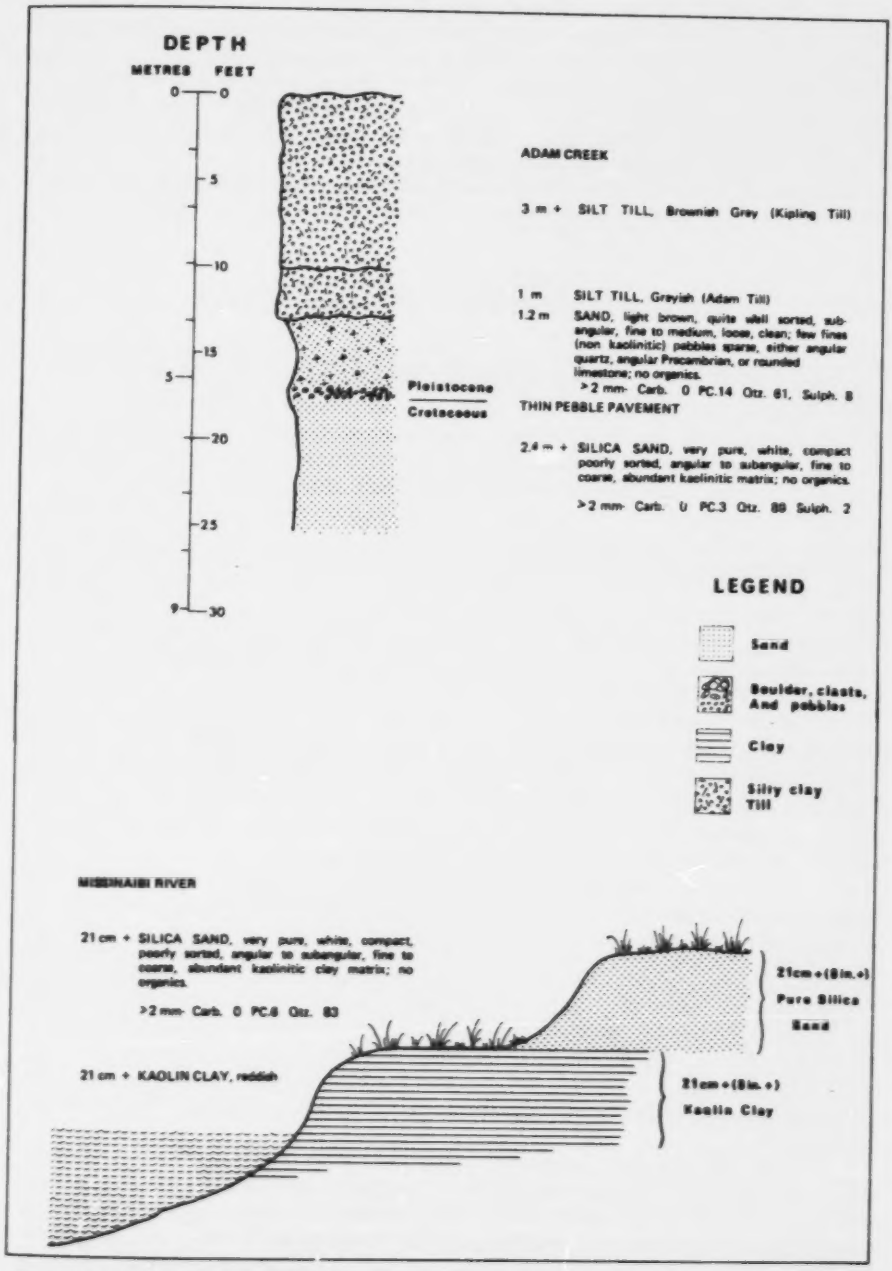
DEPTH
METRES FEET
0 0
5
10
15
5
20
25
9 30
Pleistocene
Cretaceous
ADAM CREEK
3 m + SILT TILL, Brownish Grey (Kipling Till)
1 m SILT TILL, Greyish (Adam Till)
1.2 m SAND, light brown, quite well sorted, sub-angular, fine to medium, loose, clean; few fines (non kaolinitic) pebbles sparse, either angular quartz, angular Precambrian, or rounded limestone; no organics.
>2 mm- Carb. 0 PC.14 Otz. 81, Sulph. 8
THIN PEBBLE PAVEMENT
2.4 m + SILICA SAND, very pure, white, compact poorly sorted, angular to subangular, fine to coarse, abundant kaolinitic matrix; no organics.
>2 mm- Carb. 0 PC.3 Otz. 88 Sulph. 2
LEGEND
Sand
Boulder, clasts, And pebbles
Clay
Silty clay Till
MISSINAIBI RIVER
21 cm + SILICA SAND, very pure, white, compact, poorly sorted, angular to subangular, fine to coarse, abundant kaolinitic clay matrix; no organics.
>2 mm- Carb. 0 PC.8 Otz. 83
21 cm + KAOLIN CLAY, reddish
21cm+(8in.+)
Pure Silica Sand
21cm+(8in.+)
Kaolin Clay

Figure 3.1–Sections showing Pleistocene-Cretaceous contact on Adam Creek and assumed Cretaceous red clay in river bank outcrop on Missinaibi River.

The Missinaibi River outcrop and lower white sand of the Adam Creek outcrop are very similar and presumed to be the Lower Cretaceous Mattagami Formation. As the descriptions in Figure 3.1 indicate, they differ from the upper brownish sand of the Missinaibi River outcrop (probably Pleistocene outwash) in colour, sorting, angularity, compactness, amount and type of matrix, and quartz content of sand and pebble-granule lithology. Carbonate analyses indicate that the Pleistocene sand has a total carbonate content two to three times greater than the other two, though all have quite low values. However, the effect of weathering and exposure on these samples may be great.

Summary Description of Drillhole Samples.

Full descriptions of each sample are contained in Appendix A by sample numbers as cited below.

DRILLHOLE 75-03

Samples 165, 167, 169 are brown-grey, rather poorly sorted, angular, impure, fairly coarse sands with little matrix, no organic content, and many quartz, Precambrian and limestone pebbles and granules. By contrast 171, 178, 185 are grey, well sorted and rounded, high sphericity, finer, purer, silica sand with some matrix and few pebbles and granules (little limestone). Sample 171 has many black lignite fragments. Samples 178 and 185 are from strata where Middle Jurassic palynomorphs have been found (Norris, this report). The final sample, 189, contains light brown, poorly sorted, angular, spherical, fine sand with some matrix but no organic material or +2 mm grains. A two-fold division of this hole may be made.

DRILLHOLE 75-02

Samples 125, 127, 131, 137 are brown-grey, loose weathered, sandy silt tills with few grains >2 mm (all small quartz), no organic matter but possibly carbonate cement fragments. Samples 135 and 138 form horizons within or under the tills of light brown, poorly sorted, angular, impure sand. The latter contains abundant coarse biotite, feldspar, sulphides, platy carbonate grains, whitish clays and no organic material. The >2 mm fraction is all Precambrian but original core logging indicated the presence of a granitic boulder at this level (see Figure 2.3).

Sample 139 is a grey, cohesive, sandy clay with many Precambrian granules and clay balls. The portion 141 to 149 contains greyish, moderately sorted, angular, low sphericity, fairly coarse sand without an organic constituent, but some pebbles (quartz and Precambrian). The uppermost sample (141) has much clay and some carbonate pebbles. However, 153 is well sorted, pure silica sand, while 166 is light grey clay with clay balls. Samples from 167 to 176 are com-

prised of white, well sorted, well rounded, high sphericity, fine, pure silica sand with some clay matrix but no organic component. These are very uniform sediments, except that the interval 167 to 173 has only a few granules, all of Precambrian lithologies, while 174 to 176, near the Paleozoic contact, contains a flood of angular buff limestone pebbles similar to the underlying Devonian strata. These lowest samples are similar to a basal conglomerate overlying an unconformity. In this hole sediments overlying the Paleozoic may be divided into three units at 139 and 153.

DRILLHOLE 75-05

Seven widely-spaced samples, taken from this hole for comparison with drillhole 75-06, fall into two groups of sands. Samples 26 to 28 are greyish, poorly sorted, angular, coarse, impure sands with minor calcareous clay, without organic matter. Abundant granules contain quartz and Precambrian with significant limestone. Samples 39, 78, 98, 102 consist of very white, well sorted, angular, low sphericity, very pure, fine silica sand with few granules, minor noncalcareous clay and no organics. Abundant granules in 39 are 90 percent quartz with minor limestone, and 100 percent quartz in the other three samples. Definite changes in sand character occur in the interval between samples 28 and 39.

DRILLHOLE 75-06

This hole may be divided at the base of the thick till sheet (Appendix A). Samples 57, 59, 61 are taken from a light brown-grey, massive, compact, gritty clayey silt till with few clasts (quartz or limestone), and no organics. Pure, whitish silt and clay and well sorted, angular, very fine sand with some brown organics but without pebbles makes up sample 63, whereas sample 67 is similar silty clay containing clay balls and some brown organics.

Samples 75 to 91 are essentially homogenous, containing white, well sorted, angular, low sphericity, pure, fine silica sands with abundant clay matrix and domination of quartz and Precambrian in the granules present. Brown root hairs and bark-like organics occur in sample 75, and are associated with black lignitic fragments in samples 76 and 78. Lignite is present in samples 76 to 89.

Sands in samples 93 to 138 differ from overlying sediments. They are white, moderately sorted, angular, high sphericity, somewhat less pure, medium to coarse sands with very little clay matrix and equal proportions of limestone, quartz, and Precambrian clasts in the granules. In the last two samples (134, 138) limestone and Precambrian components dominate the >2 mm fraction. In organic content, samples 93 to 97 are barren, samples 99 to 115 very rich, and below this lignite appears occasionally. Samples 105 and 107 have abundant clay-size carbon.

The upper three samples (57, 59, 61) represent one till unit whereas samples 75 to 91 appear to be a uniform sand unit. The colour and texture of the

clay and sand of samples 63 and 67 imply their affinity with the underlying sediments though the character of the organic material changes farther down, between samples 78 and 82. However, reworking prior to or during deposition of the till sheet is possible. Another sand unit from samples 93 to 138 is implied. Though similar to the overlying unit in colour, sorting and angularity, it differs in purity, grain size, matrix content, and composition of the >2 mm fraction.

Heavy Mineral Analyses

Appendix B lists heavy mineral descriptions, heavy mineral percentages, percentages of magnetic minerals, and mineral identification data for each sample analyzed.

DRILLHOLE 75-02

Heavy mineral content is quite consistent for samples 125 to 138, though samples 135 and 138, being sands, have slightly higher values due to concentration of heavy grains from the tills. Sample 139 is very low in heavy minerals, and from samples 141 to 153 values are quite variable. Beneath this level they are consistently very low. Percentages of magnetic minerals are similar, as samples 125 to 137, 138 to 166, and 167 to 176 form distinct groups. These data imply that the strata may be divided into three units at samples 139 and 153.

Sample 138 has very high hornblende and dolomite values and 7 percent dark biotite (the only occurrence of this mineral in the hole). Percentages of magnetite and ilmenite, siderite, altered pyroxene, twinned staurolite and tourmaline drop to relatively low values at this level. Sample 139 is marked by the return of hornblende, dolomite, magnetite, ilmenite, and altered pyroxene to values similar to those in beds overlying sample 138, and by the absence of biotite, and a significant increase in green-brown hornblende and pink garnet. Half of all minerals in these lower samples exhibit changes. Particularly important are the concentrations of hornblende, biotite, and dolomite, which might be expected on an unconformity, and the separation at sample 138 of two uniform, somewhat different assemblages.

The portion from samples 138-139 to 153 maintains quite uniform proportions of both hornblendes, pink garnet, magnetite, ilmenite, epidote, siderite, pyroxenes, and dolomite. Significant here are high values of green-brown hornblende and pink garnet and frequent occurrence of gold staurolite and dolomite relative to sediments above sample 138; conversely, staurolite twins and tourmaline occur less frequently.

Within 153-166-167 significant mineralogical changes occur. Sample 153 has a definite increase in pyrite and decrease in altered pyroxene. In sample 166 hornblende is near zero, pink garnet is very low, and epidote, siderite, three pyroxenes, twinned staurolite, and rutile all but disappear. In sample 167 magnetite and ilmenite, altered pyroxene, and dolomite values drop,

whereas the two garnets, gold staurolite, and tourmaline increase to relatively high, consistent values. Dolomite is notable in these three samples but rare elsewhere. These samples mark a transition into a third, deeper mineral assemblage.

DRILLHOLE 75-06

Sample 63 lying directly below the lowest till has a very low heavy mineral percentage relative to samples above and below, and a relatively low percentage of magnetic minerals. Both properties are fairly consistent below this level and different from the overlying till, though the magnetic values show sporadic highs.

Sample 63, which may separate two mineralogical units, has a relatively low percentage of blue-green hornblende and pink garnet but is high in altered pyroxene. Orange garnet, epidote, and gold staurolite also decline and remain low, whereas a flood of red-brown biotite appears. In sample 67, hornblende, garnet, and altered pyroxene return to former proportions and magnetite and ilmenite, enstatite, and rutile increase slightly. Hypersthene and clinopyroxene are slightly decreased. As in drillhole 75-02 most of the minerals appearing in these samples are affected by significant changes at this level. The concentration of biotite is regarded as most significant because this is common on unconformity surfaces (Milner 1962, p.401-402).

Several minerals change proportions at samples 93-95-97 including green-brown hornblende, pyrite and topaz becoming more abundant, and blue-green hornblende, altered pyroxene, enstatite and rutile becoming less so. Indicolite appears only in the interval samples 93 to 138 and pyrite occurs as framboids, perfect cubic crystals, and lignite pseudomorphs. This forms a third separable mineral assemblage in drillhole 75-06.

Carbonate Analyses

Data from carbonate analysis of samples in the four drillholes are listed in Appendix C.

DRILLHOLE 75-03

Upper samples 165 and 169 have rather high total carbonate percentages but samples 171 and 178 have very low total values with calcite and dolomite nearly equal. The lower samples 185 and 189 have extremely high and consistent total values with calcite over four times the dolomite percentage.

DRILLHOLE 75-02

Similar trends occur in this other northern hole (Figure 3.2). The uppermost sampled portion, samples 125 to 137, has a fairly uniform total carbonate content increasing slightly with depth, and whereas dolomite dominates over calcite, the latter also increases downward until they are nearly equal. Sample 138 is very deficient in carbonate though the calcite: dolomite ratio drops only slightly. Samples 139 to 144 have fairly consistent total carbonate and calcite: dolomite ratio values. However, sample 149 is again low in carbonate and calcite now dominates over dolomite. In sample 153 a major change appears, which continues to the Paleozoic contact, as calcite and total carbonate leap into the 30 or 40 percent range, and calcite greatly exceeds dolomite. Obvious changes occur at sample 138 and at samples 144-149-153 and the proportions are similar to those in drillhole 75-03.

DRILLHOLE 75-05

Upper samples 26 and 28 have high total carbonate values similar to those of other holes but, beneath this, all samples contain very little carbonate and dolomite generally exceeds calcite. Values are most like the very low ones obtained from the several outcrop samples of Cretaceous sands in the southern parts of the basin. This change occurs between samples 28 and 39.

DRILLHOLE 75-06

This hole, 16 km to the northwest, yielded similar data (Figure 3.3). Samples 57 to 61 display high carbonate values with the two minerals about equal. From 63 to 93 the totals are much lower, with dolomite values always about twice those of calcite. Below this, data are incomplete due to lack of fine matrix material for analysis but still indicate very high and variable total carbonate and generally equal proportions of calcite and dolomite. The analyses indicate a dolomitic but carbonate-poor layer between two carbonate-rich units in this hole.

HORNBLENDE-PYRITE RELATIONSHIPS

Visual survey of the heavy mineral analyses revealed a distinct relation between these two minerals. At the upper end of the samples in drillholes 75-02 and 75-06 the percentage of blue-green hornblende is rather high (about 30 to 48 percent in drillhole 75-06, about 22 to 40 percent in drillhole 75-02), but the percentage of pyrite is quite low (about 0 to 17 percent in 75-06, and 0 to 7 percent in 75-02) (Figures 3.4 and 3.5). At a certain stratigraphic level in each hole this relationship reverses. In the lower part of 75-06 the proportions are about

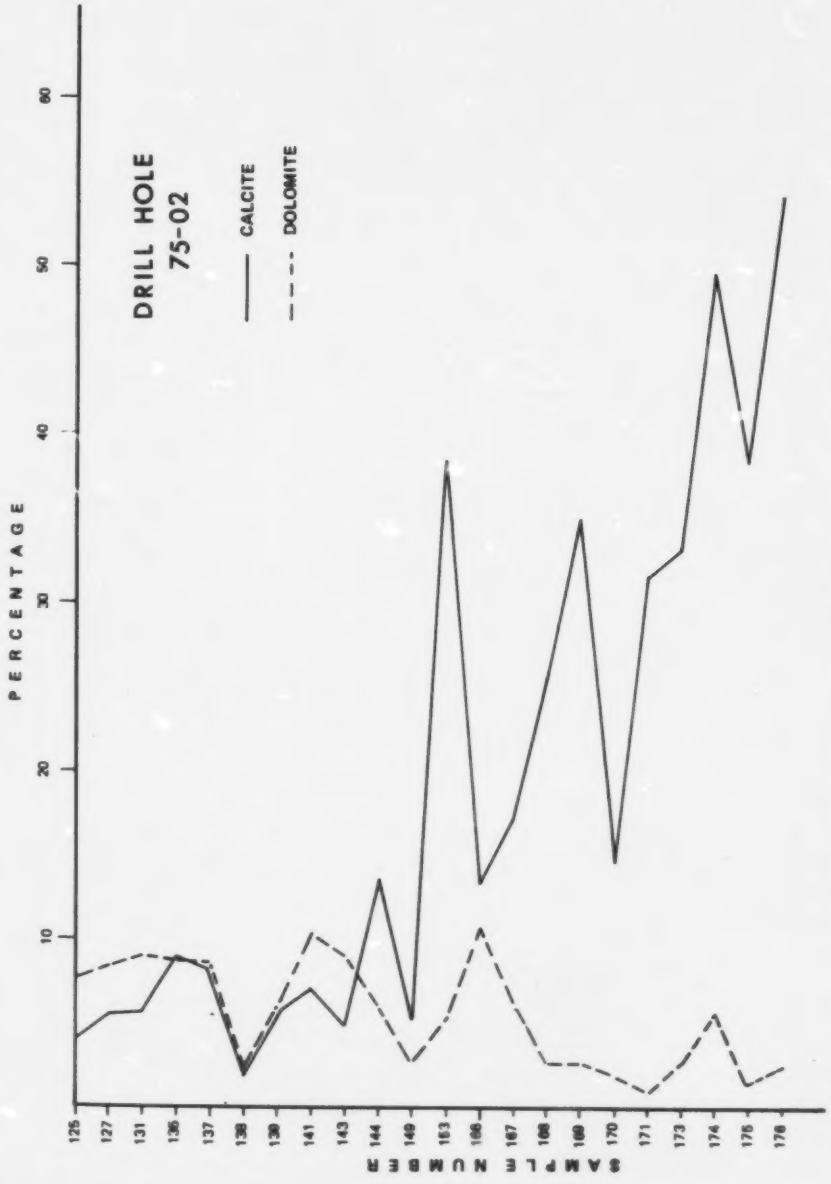

Figure 3.2–Variation in Calcite and Dolomite percentages in Matrix, Drillhole 75-02.

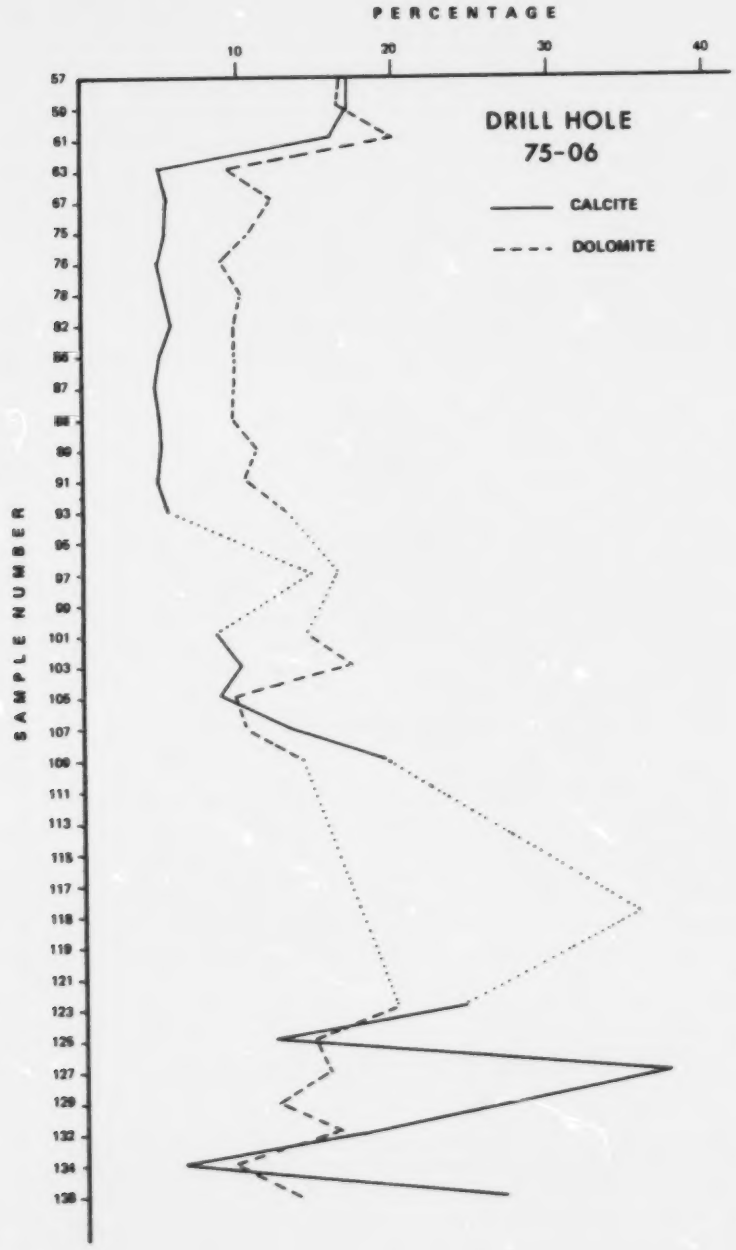

Figure 3.3–Variation in Calcite and Dolomite percentages in Matrix, drillhole 75-06.

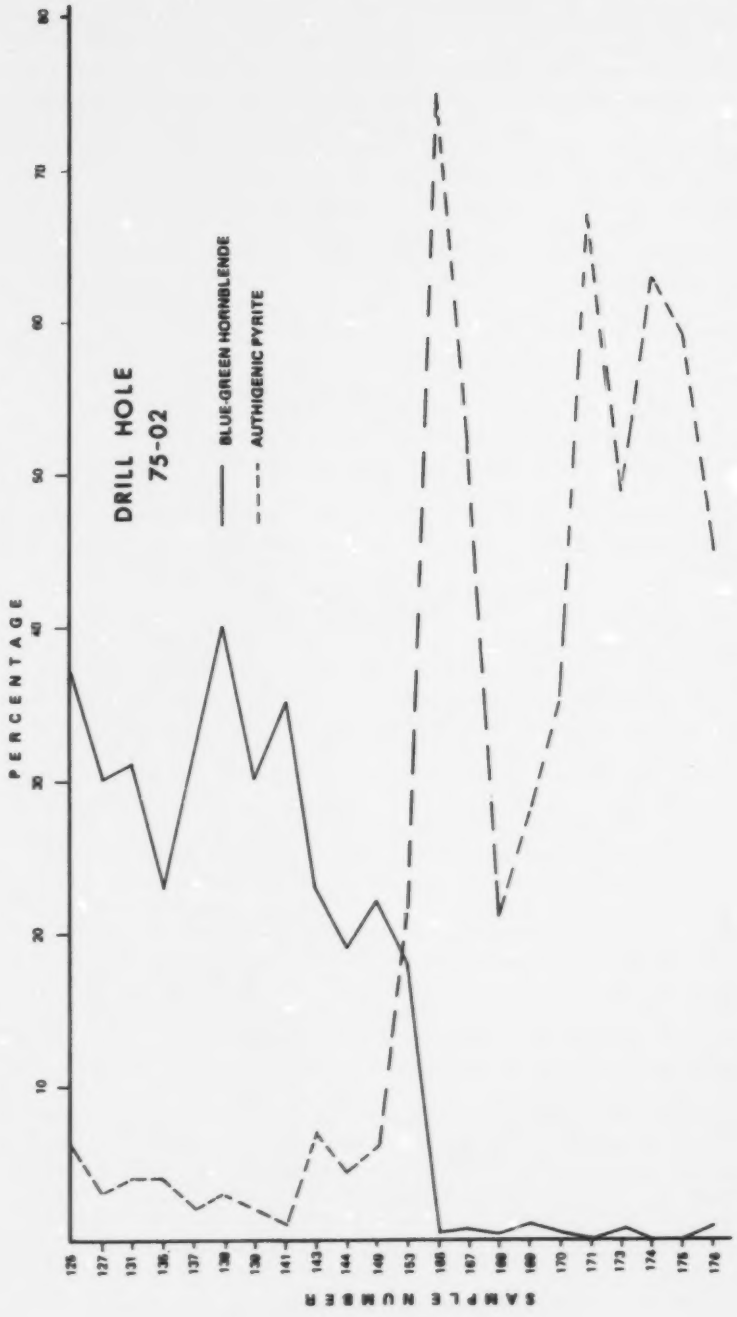

Figure 3.4-Hornblende-Pyrite Relationships, Drillhole 75-02.

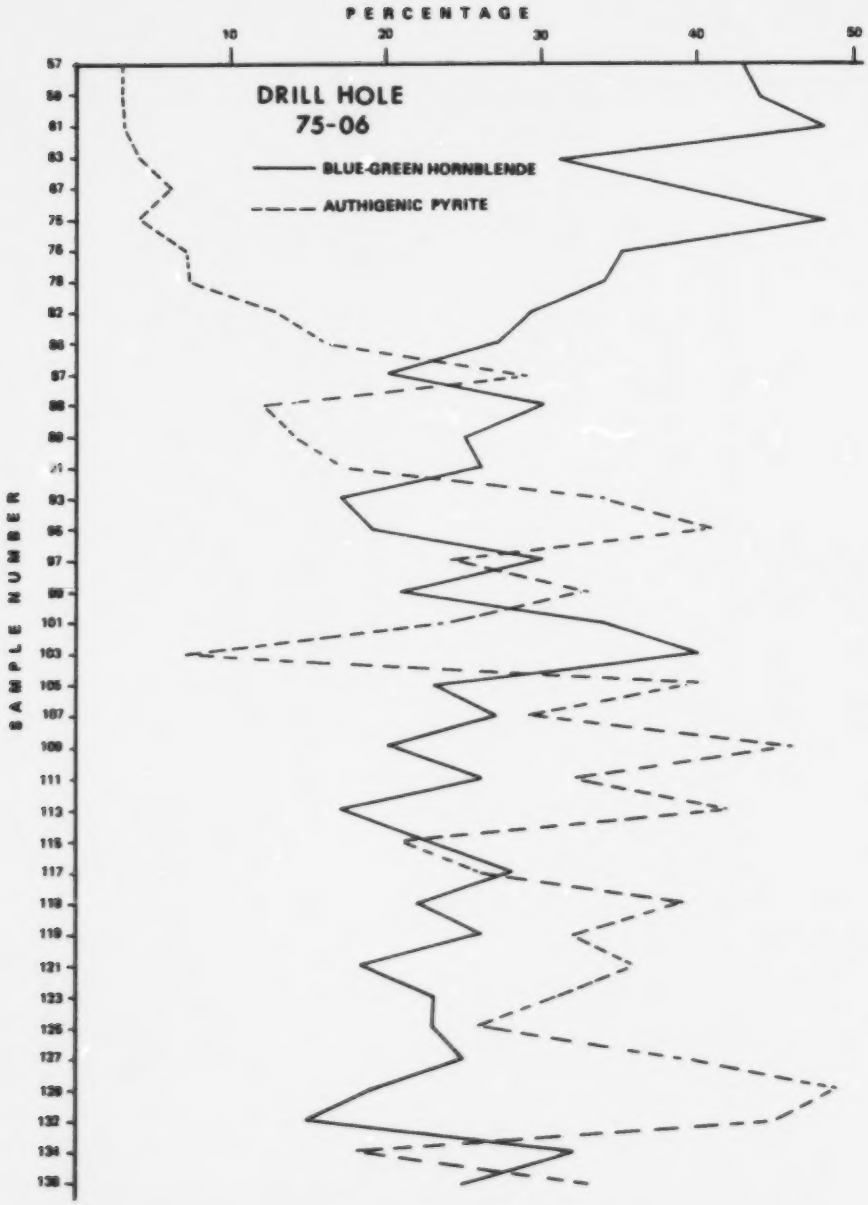

Figure 3.5–Hornblende-Pyrite Relationships, Drillhole 75-06.

15 to 30 percent hornblende and 25 to 45 percent pyrite, while in 75-02 the values are 0 to 18 percent hornblende and about 21 to 75 percent pyrite, though with much variation. Despite the variability in values, the reversal is striking. Much of the hornblende, especially in the lower parts of the holes, is altered and etched, and all pyrite appears to be authigenic.

Walker (1967) in considering Pliocene and Pleistocene red beds suggested that red colouration was due to post-burial, diagenetic transition from "normal" grey to hematite-stained red clastics resulting from groundwater processes. He reasoned that, in an oxidizing environment, groundwater circulating through porous sediments is capable of breaking down fairly unstable iron-rich silicates (especially hornblende and biotite), releasing iron atoms, and leaving montmorillonite clay as an alteration product. He proposed that iron could link with oxygen after very local transport (to prevent saturation at the point of alteration) in the solvent fluids and precipitate as fine hematite coatings on sand grains. Intrastratal alteration can occur wherever grains are in contact with suitable interstitial water and Walker's study indicates that normal ground water chemistry straddles the Eh-pH fields of both iron solution and precipitation. Slight changes in either Eh or pH could change the overall effect on iron within the sediments.

Rate of alteration depends on the amount of water moving through the sediments, though Potter (1968) noted that high clay matrix content inhibits intrastratal alteration by reducing porosity, and Walker (1967) found that hematite pigment forms first along sand laminae in mud beds. In addition to montmorillonite and iron oxides, a third product of iron silicate breakdown is calcite, precipitated as a cement. Compared to non-red lateral equivalents and surrounding beds, Walker found significant decreases in heavy mineral weight percentage (30 percent) and hornblende percentage (60 percent) within red-stained beds. However iron oxide, montmorillonite, and calcite increase and the remaining hornblende usually is badly etched and altered to clay.

Walker (1967) concluded that red beds could form in situ whenever the following six conditions are met, regardless of climate: 1) occurrence of iron-bearing detrital grains, 2) post-depositional conditions favouring intrastratal alteration of those grains, 3) interstitial Eh-pH environment favouring iron oxide formation; 4) absence of subsequent reduction of ferric iron, 5) enough time for the reactions to occur; and possibly 6) relatively warm temperature (+18°C). He regarded the authigenic hematite, the intrastratal alteration, and red beds as useful indicators of interstitial Eh and pH rather than climatic indicators.

The presence of lignite in the Mesozoic sediments of the James Bay Lowlands, likely required reducing conditions to be preserved, and the occurrence of authigenic pyrite, often in abundance, substantiate the idea of a reducing environment. Siderite also normally is stable only under low Eh conditions particularly when organic matter is present. These factors imply that at least parts of the deposit may have originated under low Eh conditions and that this character was maintained by the sediment after burial. Could a variation of Walker's post-depositional process have occurred in a reducing environment? Silica sands in the section are generally overlain by fine grained till, underlain by clay or shale, and likely would be good groundwater aquifers. If sufficient groundwater circulating through the sands was capable of diagenetically altering the abundant hornblende under the proper conditions, then secondary

clays, carbonate, and free iron could be produced, exactly as Walker found. However, under reducing conditions with abundant organic matter present, excess of carbon and sulphur ions, due to decaying organics and sulphate-reducing bacteria, is expected. Bacteria withstand high metal contents of water by rapid generation of sulphur ions from seawater sulphate which combines to render metals non-toxic by precipitation of sulphide minerals in nearshore euxinic environments (Stanton 1972). Sulphate-reducing bacteria are known to rapidly produce much sulphide if connate marine or brackish water is available. Most chemical sedimentologists now agree that these early diagenetic reactions involving alteration of detrital iron silicates and the action of sulphate-reducing bacteria are the chief source of pyrite in sediments (Berner 1971). Therefore, instead of forming hematite as in Walker's oxidizing environment, linkage of iron with abundant sulphur ions to produce pyrite is a possible explanation for the hornblende-pyrite reversals so prominent in the studied samples.

Unstable iron-bearing detritals occur as blue-green hornblende grains which tend to have a higher than normal iron content. Fine size is noted by Berner (1971) as increasing a grain's reactivity to alteration. These grains represent an adequate source of iron and contact with intrastratal solutions after deposition would allow alteration, as long as the hydraulic gradient allowed local removal of the soluble ions to prevent saturation at the point of alteration. An interstitial Eh-pH environment favouring the formation of iron sulphides is established by the presence of organics (low Eh), siderite (low Eh, likely low pH) and the authigenic nature of the pyrite itself which grows in somewhat low Eh, low pH environments (Guber 1972; Grim 1953). Preservation of organic matter and fresh euhedral pyrite with striated faces indicates little subsequent oxidation has occurred. Walker's (1967) study revealed that a few million years may be sufficient for alteration and authigenesis to take place. Mesozoic sediments therefore have had adequate time for reactions to occur. If warm temperature does enhance the reaction, the James Bay Lowlands lay considerably closer to the proposed Jurassic and Cretaceous equators than it does to the present equator (Couillard and Irving 1975). It appears that conditions for intrastratal alteration of hornblende and subsequent formation of pyrite can be met by these deposits.

Evidence that solution alteration has taken place is provided by the mineral grains. Hornblende and garnet display the surface features previously mentioned, indicative of alteration etching (Rahmani 1973). These features do not appear to be mechanically worn, hence are presumed to be post depositional. Garnet, though mechanically resistant, is chemically rather unstable and etching by acidic solutions may be quite common (Bramlette 1929). Etched and unetched grains often occur in the same sample, attributed by Rahmani (1973) to the fact that only grain surfaces facing a pore can be attacked by fluids. Alteration of pyroxene could be the result mostly of transport, though some grains are quite fresh. Alteration coatings appear on some magnetite and ilmenite grains, which normally are quite stable mechanically. The abundance of kaolin matrix in sorted, fine to coarse Cretaceous silica sand may be a product of in situ breakdown of feldspars rather than detrital clay, though kaolin is notably deficient in the lower part of drillhole 75-06. "Sawtooth" zircon overgrowths were noted in drillhole 75-06, sample 115. Alteration features gener-

ally increase in the lower portions of the drillholes. It is therefore apparent that some solution alteration has occurred.

The hornblende-pyrite relation is the most important and obvious manifestation of intrastratal solution and values for these two minerals in each drillhole were tested statistically for log normality and their correlation coefficients were calculated. This revealed a high negative correlation between abundances of hornblende and pyrite in both holes, substantiating the initial observation of an inverse relationship. In drillhole 75-06 the value is $r = -0.8748$, and in drillhole 75-02, $r = -0.8175$, which are well within the significance limits for the number of samples. This suggests, along with other evidence above, that a direct relationship occurs and that abundant hornblende seen in the upper portions of the holes has been broken down by solutions in the lower parts; the resultant iron has combined to form authigenic pyrite.

Other by-products of Walker's proposed reactions are calcite and secondary clays. Carbonate analyses for drillhole 75-06 show a distinct rise in calcite percentage to equal or twice that of dolomite in the lower part of the hole (Figures 3.2 and 3.3).

Though data are patchy due to lack of fines for analysis, the many variations in the calcite: dolomite ratio may correspond to variations in percentage of pyrite; a high calcite percentage occurs in samples with a high pyrite percentage. Drillhole 75-02 exhibits a very large increase in calcite at the level of the hornblende-pyrite reversal but this could be due to the probable Jurassic age (typically carbonate-rich sands) of the sediments. The Mattagami Formation has long been known to contain much kaolinite matrix material (up to 15 percent, Telford *et al.* 1975) but this is notably deficient in the lower part of drillhole 75-06, where the hornblende-pyrite reaction is presumed to occur, making these sands more permeable. The small amount of clay present here may result partly from the proposed process, rather than only feldspar alteration.

APPLICATION OF PETROGRAPHIC DATA

Drillhole 75-03

Original logging of this hole (Rogers *et al.* 1975) placed a Pleistocene-Mesozoic contact at 115 m depth between samples 167 and 169. However, significant changes in total carbonate percentage, colour, sorting, angularity, grain size, purity, matrix content and pebble lithology occur between 169 and 171. This complete change in character of the sands is interpreted as a major geological boundary. As mentioned, Middle Jurassic palynomorphs have been found above sample 185 and possibly up to 178 (Norris, this report) and all underlying sediments are considered as of that age.

Pure well rounded, well sorted, calcareous sands between Devonian limestone and noncalcareous, angular, low sphericity, Lower Cretaceous sands are typical features of the Middle Jurassic of the Williston Basin (L.L. Price, S.S.C. personal communication). A similar situation may exist in the Moose River Ba-

sin. Samples 185 and 189 are very calcareous. Samples 171, 178, and 185 are well sorted and rounded, high sphericity, pure, medium to coarse silica sands and can be divided from the brownish, poorly sorted, angular, impure, less calcareous sands of presumed Pleistocene age in samples 165, 167 and 169. Therefore, an unconformity between Pleistocene and Middle Jurassic sands is placed between samples 169 and 171 at a depth of 116.3 m. Abundant black lignite detritus in 171 may indicate an erosional Cretaceous residue on the unconformity.

Drillhole 75-02

This hole, 13 km to the south, contains three sedimentary units. Original logging placed a Pleistocene-Mesozoic contact at 101.2 m depth between sample 138 and 139. Heavy mineral data, carbonate analyses, and the properties of colour, sorting, compactness, composition, purity and pebble-granule lithology all indicate a major change at this level. The overlying till, being brown-grey, loose sandy and sideritic, resembles Skinner's (1973) Pre-Missinaibi Till III. In sample 153 typical Middle Jurassic carbonate values appear, and between 167 to 176 the sands are almost identical to Middle Jurassic sands of drillhole 75-03. Mineral assemblages also change radically between 149 and 166. Thus, another boundary is present in the 8 m interval between 149 and 166, possibly beneath sample 153 at a depth of 107.7 m.

Samples 139 to 149, between the Pleistocene and Middle Jurassic sections, are fairly uniform deposits of either Pleistocene sediments with some reworked Cretaceous material, or remnants of Cretaceous deposits. They have a carbonate content similar to the overlying Pleistocene, but are physically and mineralogically similar to Cretaceous sands in other holes. A single palynomorph of possible Albian (Lower Cretaceous) age was found in sample 139 (Telford *et al.* 1975). Therefore this middle interval is interpreted as an erosional remnant of a Lower Cretaceous deposit.

In summary, Pleistocene sands of the central part of the Moose River Basin (drillholes 75-02 and 75-03) may be characterized as somewhat calcareous, brownish, poorly sorted, angular, impure, medium sands with little matrix, no organics, and pebbles and granules of all compositions. They have a high heavy mineral content with high proportions of blue-green hornblende, magnetite and ilmenite, siderite, and altered pyroxene, and low pink garnet if present, have variable heavy mineral content with higher values of green-brown hornblende and pink garnet, more frequent occurrence of hypersthene, clinopyroxene, gold staurolite and dolomite, but lower siderite and twinned staurolite. These sands are medium to coarse grained, greyish, rather calcareous, moderately sorted, angular, and have low sphericity.

The Middle Jurassic Mistuskwia Beds may be defined as follows: fine to medium, pure silica sands, very calcareous, grey to white, well sorted, well rounded, with high sphericity, containing some clay matrix, limestone and Precambrian granules, but no organics. Heavy mineral and magnetic percentages are typically quite low. The sands have a characteristic heavy mineral assemblage of high pink and orange garnet, high pyrite, and relatively high values

for the unusual minerals gold staurolite and pale brown tourmaline. There are very low values of magnetite and ilmenite, epidote and altered pyroxene, only a trace of hornblende, and near absence of all other common minerals. Only the most stable and authigenic minerals are abundant indicating at least a second cycle deposit. Sorting, rounding and purity increase and grain size decreases from drillhole 75-03 to 75-02, implying a gross direction of transport from north to south.

Drillhole 75-05

Original logging by Rogers *et al.* (1975) placed a Pleistocene-Mesozoic contact at 22.5 m depth between samples 27 and 28. This petrographic analysis indicates instead that a geological boundary occurs in the 4.5 m interval between samples 28 and 39, and may be interpreted as an unconformity separating Pleistocene and Lower Cretaceous deposits. Between samples 28 and 39 significant changes in total carbonate content, colour, sorting, purity, grain size, matrix composition and pebble lithology occur. Clays underlying sample 28 are orange or reddish brown and typical of Cretaceous age sediments in other areas. The Pleistocene-Lower Cretaceous boundary is placed, therefore, immediately below sample 28 at a depth of 22.8 m.

Drillhole 75-06

A Pleistocene-Mesozoic contact was placed at 51.2 m depth, samples 61 and 63, by Rogers *et al.* (1975). Parameters studied in this project support this "pick" and indicate that it is an unconformity between Pleistocene till and underlying Lower Cretaceous sand and clay. It is defined on the basis of carbonate analysis, heavy mineral analysis, colour and especially sediment type since all Pleistocene samples are till. Those samples below sample 67 contain typical Mattagami Formation sands with a distinct mineral assemblage, low carbonate content (and dolomite dominates calcite), and black lignite occurrences. Samples 63 and 67 are grouped with the underlying Lower Cretaceous on the basis of carbonate and heavy mineral content, colour and descriptions of contained sand.

In the lower part of this hole, from sample 93 to 138, carbonate content suddenly becomes very high (with equal calcite and dolomite), clay matrix content drops and several heavy minerals change proportions. Sorting, sphericity, grain size, purity, and pebble-granule lithology are also affected and from sample 99 to 115 the lignite content is quite high. Though these sands maintain a generally similar colour, mineralogy and appearance to overlying Mattagami Formation sands, the differences are enough to warrant separation of the two units at a depth of 93.8 m.

In summary, Pleistocene sands of the southern part of the Moose River Basin (drillholes 75-05 and 75-06) consist of calcareous, greyish, poorly sorted, angular, low sphericity, impure coarse sand containing minor calcareous clay matrix, no organics and abundant limestone, Precambrian and quartz granules. Till in drillhole 75-06 contains a medium heavy mineral percentage of high

blue-green hornblende, altered pyroxene and hypersthene, medium pink garnet, some orange garnet, and low magnetite and ilmenite, pyrite, siderite and staurolite twins. The "upper" Mattagami Formation sands of 75-05 and 75-06 are poorly calcareous (with dolomite dominating calcite), white, well sorted, angular, low sphericity, very pure, fine silica sand containing much kaolinitic clay matrix, some brown and black organics, and quartz and Precambrian granules. They have a low heavy mineral content of relatively high magnetite and ilmenite, siderite, pyrite, twinned staurolite, rutile, biotite, dolomite and spinel, medium high blue-green hornblende and pink garnet, and somewhat lower pyroxenes.

The "lower" sands of drillhole 75-06 are calcareous (with equal dolomite and calcite), white, moderately sorted, angular, high sphericity, fairly pure, medium to coarse silica sand containing little matrix, abundant black lignite in places and equal proportions of limestone, quartz and Precambrian pebbles and granules. Compared to overlying sands they have a relatively higher green-brown hornblende, pyrite and topaz, and lower blue-green hornblende, altered pyroxene, enstatite and rutile percentages. Several samples contain traces of indicolite, and pyrite is very abundant, occurring as authigenic framboids, euhedral cubes and organic pseudomorphs. This unit is tentatively separated as a deposit of slightly different age, character and possibly derivation, although it is assumed to be still within the Lower Cretaceous. It differs from the overlying more typical Mattagami Formation sands in having slightly coarser grain size, higher sphericity, higher carbonate,lignite, and limestone contents, but slightly lower sorting, purity and matrix content, and contains several characteristic pegmatite and igneous minerals (topaz, indicolite, common hornblende).

SYNTHESIS OF DATA

A simplified cross-section through the Moose River Basin using information from the six winter 1975 drillholes is shown in Figure 3.6. The Middle Jurassic Mistuskwia Beds are restricted to the central part of the basin, pinching out between drillholes 75-02 and 75-04. The older phase of Lower Cretaceous deposition, which is lignite-bearing, is probably confined to the south and southeastern parts of the basin. The younger Lower Cretaceous phase extends over most of the basin but eventually pinches out in the northwest near drillhole 75-02.

Petrographic and heavy mineral characteristics for the units described in this study are listed in Table 3.2. The Middle Jurassic deposit is particularly characterized by sands with high rounding and sphericity, containing limestone (Paleozoic) and Precambrian granules, and a very restricted detrital heavy mineral assemblage. These qualities indicate a dominantly sedimentary source with minor input from metamorphosed igneous rocks. The deposit appears to be deltaic, in a general sense, and likely built out from the northwest.

The older Cretaceous phase contains high sphericity sands with a high organic content and a heavy mineral assemblage which suggests a dominantly unmetamorphosed igneous provenance (mafic and granitic/pegmatitic rocks).

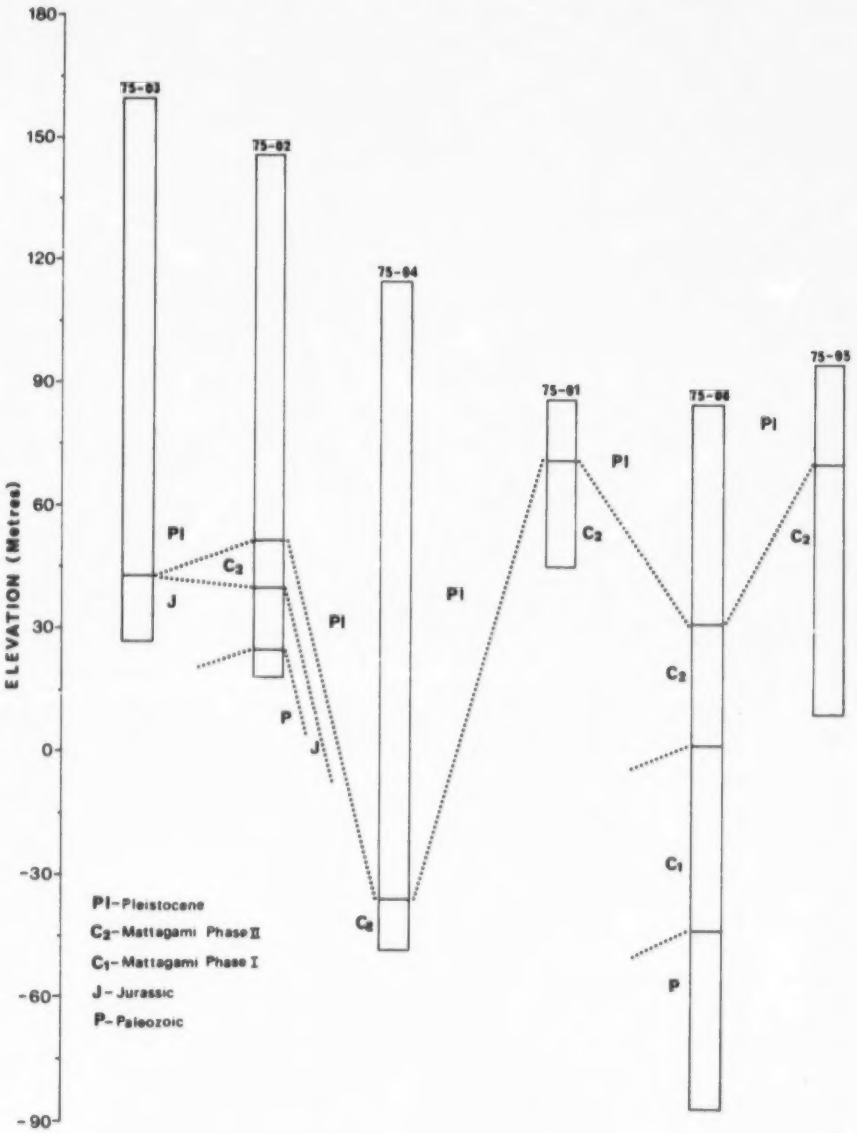

Figure 3.6–Basinal Cross Section from drillhole information.

TABLE 3.2 | PETROGRAPHIC COMPARISON OF UNITS IN THIS STUDY.

	grain size	colour	sorting	purity	roundness	sphericity	matrix-amount and type	organic content	> 2 m.m fraction	heavy minerals-amount, assemblages relative proportions*
PLEISTOCENE SANDS.	medium to coarse	brown to grey	poor	impure	angular	low	very little matrix-calcareous	none	abundant varied lithology	abundant heavies- -high bl-gr hb, pink garn., alt px, hyp. -low or. garn., pyr, mag. +ilm., sid, staur. twins.
LOWER CRETACEOUS MATAGAMI FM. PHASE II.	fine (in the south) medium to coarse (in the north)	grey to white	moderate to good	very pure	angular	low	abundant matrix, kaolinitic, poorly calcareous dol>calc.	brown and black	qtz and PC	low content- -(in south) high bl-gr hb, pink garn, mag + ilm, pyr, sid, twinned staur, rut, biot, dol. spinel - low px. -(in north) high gr-br. hb, pink garn, hyp, cpx, gold staur - low sid, twinned staur.
LOWER CRETACEOUS MATAGAMI FM. PHASE I - (exposed only in southern part of basin)	medium to coarse	white	moderate	pure	angular	high	little matrix-calcareous, dol = calc.	abun-dant, black.	varied lithology	-high gr-br.hb., pyr, topaz -low bl-gr. hb., alt px, enstat., rutile. -traces of indicolite.
MIDDLE JURASSIC (exposed only in northern part of basin)	fine to medium	grey to medium	good	pure	well rounded	high	very calcareous	none	Ls and PC	low content- -high pink garn, pyr, or. garn, brown tourm, gold staur. -low hb, mag + ilm, epid, alt px. -most other minerals only trace or absent

* see p87 for mineral abbreviations

This initial deposition from the Precambrian Shield in the south may have begun with fault movement at the southern edge of the basin, and may represent another deltaic deposit. The second phase of Cretaceous sedimentation, which blankets much of the basin, is distinguished by its purity and kaolinitic matrix. The different grain sizes and heavy mineral assemblages in central and southern parts of the basin may indicate several deltaic systems draining somewhat different terrains. However, the assemblages in both drillholes 75-02 and 75-06 imply a metamorphosed igneous (dominantly intermediate to mafic rocks) source area on the Shield.

Pleistocene deposits consist of glacial till and likely glaciofluvial sands. The sediments generally are poorly sorted, impure and contain an abundant and varied heavy mineral assemblage. Undoubtedly some of the material is recycled from underlying Mesozoic and Paleozoic sediments, as well as from metamorphosed igneous rocks on the Shield.

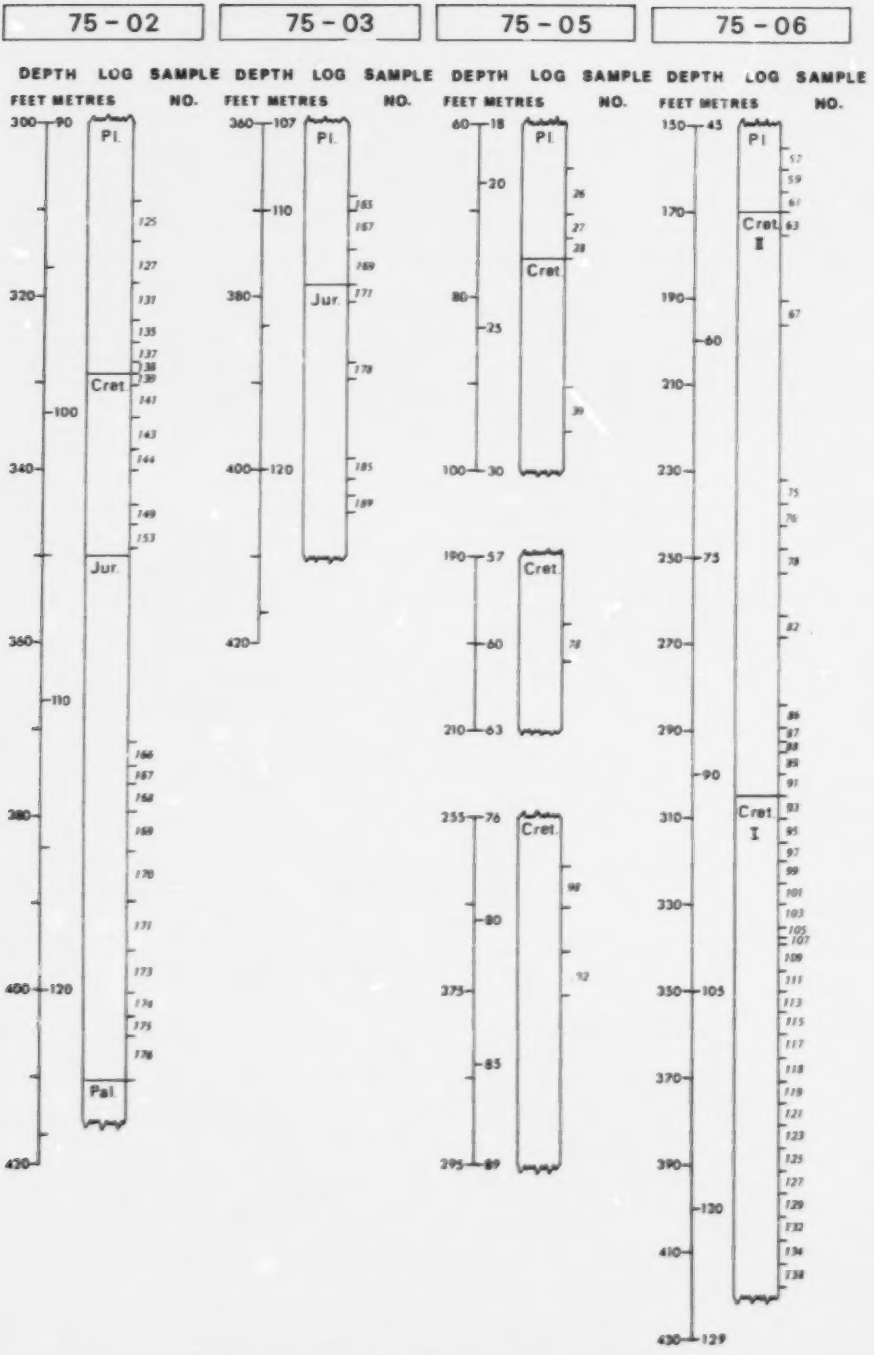

Figure 3.7–Location of Samples studied 1975 drillholes.

APPENDIX A

Sample descriptions from: drillhole 75-02, drillhole 75-03, drillhole 75-05, drillhole 75-06

Note: More complete logs are contained in Rogers *et al.* 1975.

Sphericity and quartz percentages provided by P.G. Telford, Ontario Geological Survey.

Abbreviations

Bl. PC.	Black Precambrian	PC	Precambrian
Bl. Ss.	Black Sandstone	qtz	quartz
carb.	carbonate	Ss	Sandstone
		sulph	sulphide

DRILLHOLE 75-02

Sample Descriptions

125- brownish grey, sandy, clayey silt till, with very few small quartz pebbles; not too cohesive; lots of fines; no organics; likely some carbonate cement fragments.

127 - brownish grey, sandy, clayey, silt till with very few small quartz pebbles; crumbly; lots of fines; no organics maybe carbonate cement fragments.

131 - brownish grey, not too cohesive, quite sandy, clayey silt till, with very few small quartz pebbles; no organics.

135 - brownish, poorly sorted, fine and coarse sand, with quartz concentrated into finer size; also some limestones, and few Precambrian granules; possibly better rounded in finer sizes; lots of fines; no organics; >2 mm—carb.3, PC.1, Bl.PC.1, qtz.0.

137 - brownish grey, sandy silt till, with few quartz pebbles; not very cohesive; lots of fines; no organics.

138 - light brownish, moderately sorted, quartz sand with some limestones and iron grains; high content of coarse biotite, K feldspar, plagioclase, quartz, grains (from granite boulder) and carbonate cement fragments; many sulphide grains; lots of white fines; no organics; >2 mm—carb.0, PC.22, Bl.PC.0, qtz.0, sulph.3.

139 - grey sandy, pebbly quite cohesive, clay till containing quartz grains and limestone pebbles and clay balls; lots of fines; no organics; >2 mm—carb.8, PC.2, Bl.PC.19, qtz.7, Red PC.2.

141 - brownish grey, very poorly sorted, subround to subangular; high sphericity; fine to coarse silty sand with quartz concentrated in finer size, limestone and some Precambrian in coarser size; many medium small rounded limestone pebbles; 90% quartz; no organics; >2 mm—carb.8, PC.5, Bl. PC.19, qtz.2.

143 - moderately well sorted, fairly angular, medium grained silica sand, with some limestone and Precambrian grains, some coarse grains; no pebbles; some balls of sand and clays; low sphericity 95%; >2 mm—carb.1, PC.0, Bl. PC.3, qtz.3.

144 - rather poorly sorted, angular to subangular, low sphericity, some high, coarse to very coarse silica sand with many limestone and Precambrian grains and rounded limestone and subangular Precambrian pebbles; sand 98% quartz; almost no fines; no organics

149 - greyish, moderately sorted, angular to subangular, medium to me-

dium coarse grained silica sand, with some limestone and Precambrian grains; few fines; no organics; >2 mm—carb.2, PC.7, Bl.PC.4, qtz.14.

153 - well sorted, pure, medium grained silica sand with some coarser, mostly Precambrian, grains; no pebbles or granules; some fines; no organics.

166 - very light grey, slightly silty clay, some sand-size clay balls; lots of fines; no organics.

167 - very well sorted, well rounded; high sphericity; pure, 99% quartz, fine to very fine grained silica sand; some light grey slightly silty clay bits, former laminae; lots of fines; no organics.

168 - very well sorted, well rounded; high sphericity; whitish, pure, 99% quartz, medium fine silica sand with very fine Precambrian laminae(?); some fines; no organics.

169 - very well sorted, well rounded; high sphericity; whitish, clean, pure, 99% quartz, fine to very fine grained silica sand, with a few pyrite grains; some fines; no organics.

170 - well sorted, well rounded; high sphericity; whitish fine to very fine silica sand, 99% quartz, with some Precambrian grains; also few coarse quartz grains; some fines; no organics.

171 -moderately sorted, well rounded; high, some low, sphericity; very fine to medium silica sand with fair number of Precambrian and some sulphide grains; 95% quartz; lots of fines; no organics; >2 mm—carb.0, PC.5, Bl.PC.2, qtz. 0.

173 - very well sorted, well rounded, whitish, fine to fine-medium grained silica sand, with fair number of Precambrian grains, and possible brown dolomite granules; some sulphide grains, balls of sand and fines; some fines; no organics; >2 mm—carb.0, PC.2, Bl.PC.1, qtz.0.

174 - poorly sorted, well rounded, medium to medium-coarse silica sand, subangular buff limestone and Precambrian pebbles - in sand are coarse sulphide and Precambrian grains - some fines, though not much; no organics; >2 mm fraction totally dominated by angular limestone; abundant pebbles and granules.

175 - medium sorted, mostly well rounded, very fine to fine or fine-medium silica sand, with some Precambrian grains; fair number of angular buff limestone granules and coarse sand-size grains (note presence of limestone boulder at this level); lots of fines; no organics; no pebbles or granules.

176 - sorted, well rounded, fine grained silica sand with many angular buff limestone granules and pebbles, and some Precambrian; also some coarse quartz granules, angular, and Precambrian grains in sand; some fines; no organics; >2 mm—carb.42, PC.1, Bl.PC.2, qtz.0.

DRILLHOLE 75-03

Sample Descriptions

165 - brownish grey, poorly sorted, angular to subangular, not too pure, fine medium to very coarse sand, mostly quartz but also fair bit of Precambrian and

some limestone grains and granules; black Precambrian and limestone tend to be rounded; no fines; no organics; some rounded quartz grains, but only a few; >2 mm—carb.11, PC.35, Bl.PC.20, qtz.27.

167 - grey brown, medium sorted, angular to subangular, fairly pure, fine medium to coarse silica sand with some granules and very coarse grains; some rounded quartz and limestone grains; most impurities are Precambrian; no fines; no organics; is more rounded quartz than sample 165; >2 mm—carb.6, PC.15, Bl.PC.9, qtz.24.

169 - grey brown, poorly sorted, angular to subangular, low and high sphericity, fine medium to very coarse sand with granules, 95% quartz; lots of Precambrian grains; some rounded quartz grains no fines; no organics; quite a few large granules or small pebbles; most sand in medium to coarse range; >2 mm—carb.5, PC.33, Bl.PC.10, qtz.32, red Ss.2, chert 3.

171 - greyish, well sorted, fairly well rounded (with some angular grains), high sphericity (.85-.97), fine to fine medium very pure, 97% quartz, silica sand with many large and small lignite fragments any non-quartz grains are Precambrian; almost no fines; abundant lignite fragments, black.

178 - dark grey, fairly well sorted, mostly very well rounded, (impurities not as well as quartz), high sphericity, sort of impure (relatively), 95% quartz, medium to coarse sand with a few granules and small pebbles; grains other than quartz nearly all black; some cement; some fines; a few angular quartz grains; no organics; >2 mm—carb.0, PC.3, Bl.PC. or Bl.Ss. 12, qtz.0.

185 - grey, fairly well sorted, mostly well rounded (with some angular quartz), high sphericity, medium to coarse quartz sand, 95% quartz, fair number other grains, a few very coarse or granule sizes too; some cement; some fines; most non-quartz grains black; no organics; >2 mm—carb. 2, PC.10, Bl.PC. or Bl.Ss.9, qtz.3, sulph.2, chert 1.

189 - light brown, rather poorly sorted, subangular (with a few rounded quartz), high sphericity, very fine to medium sand, 97% quartz, with some granules and small pebbles and very coarse sand grains; some cement; some fines; no organics; >2 mm—0.

DRILLHOLE 75-05

Sample Descriptions

26 - greyish, rather poorly sorted, angular to subangular, fine to very coarse silica sand with; many subangular Precambrian grains and some granules; no fines; no organics; >2 mm—carb.10, chert 2, red Ss.2, PC.26, Bl.PC.13, qtz.18.

27 - rather poorly sorted, angular to subangular, coarse pebbly sand and gravel; coarse sand to small pebbles; bulk of material in granule and pebble size; much is quartz but much also of subangular to subround Precambrian and limestone; no fines; no organics; >2 mm—carb.7, PC.20, Bl.PC.13, qtz.32.

28 - moderately sorted, light greyish, angular, coarse to very coarse silica

sand with some granules and small pebbles; many subangular Precambrian. Some limestone grains and granules; no fines; no organics; >2 mm—carb.18, PC.30, Bl.PC. 18, qtz. 65.

39 - whitish, angular to subangular, low sphericity, fairly well sorted, medium to coarse, very pure, 99% quartz, silica sand with some quartz granules almost nothing but quartz and what else there is is medium Precambrian grains some rounded limestone granules some fines (is kaolin, white) some cementing, but not calcareous no organics; >2 mm—carb.1, PC.4, Bl.PC.1, qtz.89.

78 - very white, quite well sorted, angular to subangular, high sand low sphericity, fine very pure (99% quartz) silica sand with a few medium and coarse grains only tiny proportion is not quartz and all that is dark Precambrian few fines (white kaolin), non-calcareous, no organics; >2 mm—only one quartz granule.

98 - very white, quite well sorted, angular to subangular, very pure fine grained silica sand with a few medium and coarse grains almost all quartz with a couple of dark Precambrian grains also several muscovite flakes noted possibly some white kaolin clay fines non-calcareous, no organics; >2 mm—0.

102 - very white, fair sorted, angular to subangular, very pure, fine to medium silica sand with a few coarse sand grains, couple granules almost all quartz, only traces of dark Precambrian grains some muscovite flakes some white kaolin clay fines non-calcareous, no organics; >2 mm—4 quartz granules.

DRILLHOLE 75-06

Sample Descriptions

57 - very light brownish grey, massive, cohesive, hard, gritty, clayey silt till with a very few granule size angular quartz and rounded limestone clasts; no pebbles; abundant fines; no organics

59 - very light brownish grey, massive, cohesive, hard gritty, clayey silt till with a very few granule size angular quartz and rounded limestone clasts; no pebbles; abundant fines; no organics.

61 - very light brownish grey, massive, cohesive, compact, gritty, clayey silt till with a very few granule size clasts of quartz, few rounded limestone; no pebbles; abundant fines; no organics.

63 - very well sorted, subangular to angular, light grey or whitish, pure, silt and clay (quartz) with very fine sand too; some Precambrian grains and a few quartz medium sand grains and clay balls; no pebbles; abundant fines; very tiny organics, mostly fine brown root hairs.

67 - very well sorted, light grey or whitish, slightly gritty (clayballs), silt and clay with only a couple fine sand grains; no pebbles or granules or coarse sand; abundant fines; possible few organics.

75 - very well sorted, angular to subangular, high and low sphericity, white, very pure, 97% quartz, very fine silica sand with a few quartz and Precambrian coarse sand size grains; no pebbles or granules; no feldspar; lots of

fines, much silt and clay; some brown root hair and barky organics.

76 - very well sorted, subangular, high and low sphericity, white, pure 93% quartz, very fine sand with a very few coarse size quartz grains; no pebbles, or granules; no feldspar; lots of fines; a few black organics, coarse size, and some brown.

78 - very well sorted, subangular, low sphericity, very fine to fine, quite pure, 98% quartz, silica sand, whitish colour, with some Precambrian grains; a couple of medium grained quartz grains; no pebbles of granules; feldspar; lots of fines; a few black lignite fragments and root hairs.

82 - moderately poorly sorted, angular to subangular, fairly pure, very fine to medium silica sand with some coarse sand and lignite grains; no feldspar noticed; no pebbles or granules; lots of fines; very minor black lignite.

86 - quite poorly sorted, subangular, low,some high sphericity, very fine to coarse silica sand, 93% quartz, with Precambrian grains and limestone and Precambrian granules; bulk is fine sand of quartz with Precambrian; lots of fines; few black lignite fragments.

87 - whitish colour, fairly well sorted, subangular to subrounded, low sphericity, very fine to fine pure sand and silt, 98% quartz, with some quartz and Precambrian very coarse sand and granules; no pebbles; lots of fines; a few very small black lignite fragments.

88 - well sorted, subangular, low sphericity, whitish, pure, 98% quartz, very fine sand with some Precambrian grains, and also some coarse sand grains or quartz and Precambrian (and of course the lignite fragments); no pebbles or granules; lots of fines; abundant small black lignite fragments with couple of brownish root hairs.

89 - poorly sorted, very fine to very coarse, angular to subangular, low sphericity, silica sand, 98% quartz, with more limestone and Precambrian in coarser fraction than finer (mostly quartz); no pebbles or granules; lots of fines; rare tiny black lignite fragments.

91 - poorly sorted, very fine to very coarse, angular to subangular, low sphericity, silica sand, 90% quartz, the finer sizes being concentrated in silica, the coarser has Precambrian and limestone and quartz; no pebbles; lots of fines; no organics.

93 - poorly sorted, subangular, high sphericity, medium to coarse silica sand, 97% quartz, with Precambrian and limestone grains and many fines as matrix, and a few granules and pebbles of quartz, Precambrian, and rounded limestone; lots of fines, mostly silt size; no organics; >2 mm—carb.20, PC.17, Bl. PC.6, qtz.26.

95 - moderately well sorted, medium to coarse, angular to subangular, high, some low sphericity, sand, 97% quartz, with many Precambrian grains and some small rounded limestone grains; also a few quartz and Precambrian granules or small pebbles; no fines; no organics.

97 - moderately sorted, angular to subangular, high, some low sphericity, medium coarse to very coarse silica sand, 97% quartz, with many Precambrian and some limestone rounded grains; is also medium sand (mostly silica) - only a few pebbles; very few fines; no organics; >2 mm—carb.5, PC.5, Bl.PC.1, qtz.8.

99 - moderately well sorted, subangular, high sphericity, medium to medium coarse silica sand, 95% quartz, with Precambrian and some smaller limestone grains; a few Precambrian granules; no pebbles; no fines; possible small black lignite fragments.

101 - well sorted, angular to subangular, fine, pure silica sand with some limestone and Precambrian and some medium quartz grains; some fines; few tiny black, brown, lignite fragments; more than sample 103.

103 - very well sorted, angular to subangular, very fine grained, pure silica sand, with some Precambrian and dolomite but not much, few fines; some tiny black lignite fragments; not as much as sample 105.

105 - poorly sorted, angular to subangular, very coarse sand to medium pebbles size gravel of Precambrian, some limestone, some quartz (minor sulphide), with matrix of poorly sorted very fine to medium sand; almost no fines; abundant lignite in all sizes; black lignite pebbles, also very black carbonaceous clays.

107 - moderately sorted, angular to subangular, medium fine to medium silica sand with some Precambrian and few limestone and couple quartz granules; most of medium sand and coarser grains are quartz; some fines; abundant black, some brown lignite fragments, often of coarse sand size; also very black carbonaceous clays.

109 - moderately sorted, angular to subangular, fine to medium silica sand with some Precambrian and limestone grains, and some quartz granules, and a few limestone and Precambrian small subround pebbles; almost no fines; some lignite fragments and small pebbles.

111 - well sorted, angular to subangular, fine to fine medium silica sand with some Precambrian and limestone grains and lignite fragments; no pebbles; no fines; some black and grey lignite fragments.

113 - rather poorly sorted, subangular to subround, granular to medium pebble gravel of light and black Precambrian, carbonate, and not much quartz at all; also lignite pebbles showing good woody character; some moderately sorted fine silica sand matrix though not much; fines; some black lignite pebbles.

115 - moderately poorly sorted, angular to subangular, very coarse sand to granular gravel of quartz, Precambrian, limestone with many rounded limestone and black Precambrian and angular Precambrian small pebbles only trace of dark grey fines; few pebble-size black lignite frags.

117 - moderately sorted, angular to subangular, very coarse sand to granular gravel (quartz and Precambrian, with some limestone) with many small pebbles of angular quartz and Precambrian, and rounded carbonate; black Precambrian tend to round more than felsic; no fines; no organics.

118 - poorly sorted, angular, impure, fine to very coarse sand of quartz, Precambrian, rounded limestone with a few small Precambrian pebbles almost no fines; no organics.

119 - moderately well sorted, angular to subangular, fine to fine medium silica sand, with some Precambrian and small limestone grains, and some coarse and very coarse sand grains; no pebbles; no fines; few very tiny black lignite fragments.

121 - moderately well sorted, angular to subangular, medium to coarse-grained sand with many angular Precambrian and fair number subround limestone grains; no pebbles; no fines at all; possible few black lignite fragments.

123 - well sorted, subangular, medium fine, fairly pure silica sand, with some limestone and Precambrian grains, and also some Precambrian and quartz coarse sand grains; no pebbles; almost no fines; no organics.

125 - moderately sorted, angular to subangular, medium to coarse sand with some more rounded fine sand; mostly of quartz with Precambrian and limestone; few fines; possible few tiny lignite fragments.

127 - poorly sorted, angular to subangular, fine to coarse sand of quartz, Precambrian and some limestone; with some subangular Precambrian and rounded limestone pebbles; few fines; no organics.

129 - moderately well sorted, granular, very coarse sand of quartz and Precambrian with less Paleozoic (noticeable, angular, fresh, K feldspar), some sulphides; with a matrix of poorly sorted fine to medium silica sand; angular to subangular, though limestone tends to be subround; some pebbles; very few fines; no organics; >2 mm—carb.51, PC.33, Bl.PC.23, qtz.40.

132 - moderately poorly sorted, angular, low sphericity, fine to medium coarse silica sand, 98% quartz, with some Precambrian and a few tiny limestone grains; few fines; no organics.

134 - moderately sorted, very fine to medium coarse, subangular, quartz sand with a fair number of limestone and Precambrian grains; lots of fines; some pebbles; slight possibility couple tiny lignite fragments, may be shale; >2 mm—carb.20, PC.17, Bl.Ss.8, qtz.16.

138 - moderately poorly sorted, angular to subangular, fine to medium coarse grained sand, 98% quartz, with many Precambrian and buff limestone grains; high sphericity; some carbonate cement fragments; some pebbles; not much fines; no organics; >2 mm—carb.33, PC.15, Bl.Ss.7, qtz.10.

APPENDIX B

All mineral proportion values are percentages of total heavy mineral separate.

Heavy Mineral Descriptions

Twenty-three heavy mineral species were identified in the 2μ to 3μ fraction and represent 0.24 to 11.54 percent by weight of the sand samples. Milner (1962) and Krumbein and Pettijohn (1938) were used as guides to identification. The bulk of each count consisted of hornblende, garnet, pyroxene and pyrite. Separates were not treated with acid and consequently soluble siderite, hypersthene and heavy dolomite remain intact. In general, grains in drillhole 75-02 appear more altered than those of drillhole 75-06. Following are brief descriptions of the form and distribution of each mineral species. Only certain stratigraphic intervals of each drillhole were analyzed and so the terms "upper" and "lower" indicate levels within these intervals.

HORNBLENDE

Hornblende, a major heavy mineral constituent, is nearly all of the blue-green, sodium- and iron-rich metamorphic variety. It occurs as thick, longitudinally-cleaved, weathered laths, which are often larger than other minerals, nearly opaque in the centre and strongly pleochroic, especially at the edges. It tends to be subangular to subround though many grains in the lower segment of drillhole 75-06 have "hacksaw" notched terminations and pockmarks, attributed by Rahmani (1973) to solution etching. This mineral is rare or absent in lower samples of drillhole 75-02. It accounts for 15 to 48 percent of separates in drillhole 75-06 and 0 to 40 percent in drillhole 75-02. "Common" green-brown pleochroic hornblende of similar appearance forms a minor component (less than 4 percent) of some samples.

GARNET

Purple-pink almandine makes up 9 to 19 percent of drillhole 75-06 samples and 4 to 38 percent of drillhole 75-02, notably high in the lower part of the latter. In the upper part of both drillholes the grains appear fresh, clear, angular and conchoidal-fractured, but deeper a few well-rounded grains and some with pitted and grooved surfaces (like the "imbricate wedge markings" produced by etching; Rahmani 1973)) begin to occur, as do grains with inclusions. The lower section of drillhole 75-02 contains a large proportion of garnets, all well-rounded and with surface alteration features. Garnet with pale to deep orange tints is a minor component of some samples, but ranges up to 8 percent in the lower parts of drillhole 75-02. Some of these grains may be pyropic.

PYRITE

Authigenic pyrite, encountered in all samples, reaches major proportions in the lower part of each hole, particularly drillhole 75-02. It makes up about 3 to 49 percent of heavy mineral particles in drillhole 75-06 and 1 to 75 percent in drillhole 75-02. The perfect cubic crystal form with striated faces, unweathered framboidal aggregates, and delicate pseudomorphing of fossil plant matter negate a detrital origin. It is not a stable mineral in transport and all grains appear to have formed in situ. The pyritized plant fragments are abundant in the lower part of drillhole 75-06 but are absent in drillhole 75-02 which is dominated by euhedral cubic aggregates. Some grains have clinging calcite and quartz grains, especially in drillhole 75-02.

PYROXENE

Orthopyroxene occurs both as ubiquitous, brightly-pleochroic (orange-pink to green) hypersthene grains of varying size, some with schiller-structure and as less consistent, more altered, colourless enstatite laths. Clinopyroxene (likely diopside dominating) is also present as colourless to pale or darker green grains, occasionally diallagic and usually altered to some extent. Several bright grass green grains were noted which may have significant chromium content. All pyroxenes were poorly rounded, showed some alteration to a whitish material and had hackly terminations, this effect increasing with depth. An additional class was counted, referred to as 'altered pyroxene', indicating unidentifiable, often spherical, white or greenish white masses presumed to be totally or surficially altered grains of pyroxene. Identifiable types represent up to 15 percent of any sample but disappear in the lower part of drillhole 75-02, while altered pyroxene represents an additional 0 to 15 percent and occurs in all samples.

MAGNETITE AND ILMENITE

These minerals were lumped together for ease of counting because differentiation can be difficult. They are ubiquitous as equigranular, subangular, grey to black metallic grains but only in the upper portion of drillhole 75-02 do they comprise more than 10 percent of any separation. Magnetite sometimes has a rusty alteration coating and ilmenite may have a whitish coating of leucoxene.

EPIDOTE

Greenish yellow epidote occurs in most samples and is very constant in abundance (0 to 5 percent), size, shape, and surface features. The small, equigranular, rather angular, usually somewhat altered and fractured grains have

strong pleochroism from colourless to pale green or yellow. The percentage decreases significantly in the lower portion of drillhole 75-02.

SIDERITE

This mineral appears as globular aggregates of small euhedral crystals, but mostly as worn, massive, equidimensional grains comprising 0 to 9 percent in drillhole 75-06 and 5 to 16 percent in the upper part of drillhole 75-02, though absent in the lower part. Colour ranges from yellow through orange to red-orange and usually the masses are nearly opaque to transmitted light. Most is detrital, possibly derived from siderite occurrences in Devonian limestones, though some may be authigenic.

STAUROLITE

Two types of staurolite are found: gold staurolite as clear, fresh, subangular to subround, fairly equant, pleochroic (golden yellow to colourless) grains common only in the lower part of drillhole 75-02, and twinned staurolite as worn, pleochroic, dusky, cross-twinned crystals containing dark inclusions, which tend to stand up in the mounting medium and appear with a characteristic "hay sheaf" shape under the microscope. The latter are more common and make up 0 to 6 percent of drillhole 75-06 and the upper samples of drillhole 75-02 (absent in the lower part). These also show a radiate internal structure. Euhedral, flat-lying cruciform twins were noted in drillhole 75-06, samples 75 and 76. Gold staurolite may contain abundant quartz inclusions giving it a "swiss cheese" appearance.

BIOTITE

Biotite is present in only one sample (138) of drillhole 75-02 comprising 7 percent of green-brown, ragged, warped, basal cleavage flakes containing some inclusions. It is more widespread in drillhole 75-06 but here consists of fresh, bright red-brown, wavy basal flakes with dark haloed inclusions. Each sample contains no more than 1 percent except samples 63 (14 percent) and 75 (4 percent).

OTHERS

Trace amounts of pale brown to colourless, dusky, euhedral zircon crystals with many fine inclusions, some surface markings and a few "sawtooth" outgrowths occur in some samples. Apparent pleochroism is due to large differences in different grain orientations. Elongate, broken and striate, or subround

to subangular flakes of tourmaline with yellow-brown, or purple, to throughout. Three lower samples in drillhole 75-06 contain trace amounts of indigo blue, very weakly pleochroic indicolite. Dark red-brown rutile, usually less than 1 percent, is small and equant, has black borders, extreme birefringence and is nearly opaque. Colourless spinel is rare but present in three samples of drillhole 75-06, while the coffee-brown picolite variety in equant fractured grains, makes up trace amounts of several samples in each drillhole. Anhedral to subhedral, colourless basal sections of topaz comprise 1 percent or less of samples in drillhole 75-06 and the upper part of drillhole 75-02. A few percent of heavy dolomite, usually as clear rounded or broken grains, occurs in many samples.

HEAVY MINERAL ANALYSES

DRILLHOLE 75-06

Sample Number	-60+125 Mesh. Grams	Heavy Mineral %	Mag. %
057	9.47	1.70	9.32
059	8.26	1.61	19.55
061	7.76	1.29	13.00
063	1.26	.87	9.09
067	3.06	1.47	11.11
075	5.57	.75	4.76
076	9.70	1.80	6.86
078	16.06	2.18	4.85
082	10.11	2.27	6.55
086	13.87	2.42	8.95
087	6.62	4.26	8.51
088	12.12	1.98	5.83
089	9.60	3.78	6.61
091	11.26	2.51	4.95
093	1.60	4.44	8.45
095	0.18	6.67	16.67
097	1.47	8.30	9.84
099	2.44	8.07	8.63
101	28.25	4.40	6.84
103	40.11	2.49	4.71
105	1.44	4.17	8.33
107	16.50	3.21	5.66
109	4.36	8.26	8.61
111	5.94	5.22	6.77
113	0.42	8.33	11.43
115	0.19	4.21	25.0
117	0.40	1.75	42.9
118	3.58	2.99	5.61
119	4.94	.55	8.12
121	1.23	6.02	5.41
123	7.31	5.76	6.89
125	6.42	2.51	5.59
127	3.13	6.55	7.80
129	3.31	7.76	6.23
132	11.16	7.50	12.78
134	12.57	5.11	7.62
138	15.30	4.86	4.58

DRILLHOLE 75-02

Sample Number	-60+125 Mesh. Grams	Heavy Mineral %	Mag. %
125	11.83	1.28	4.64
127	12.95	1.56	8.91
131	11.90	1.65	7.65
135	13.27	2.24	8.75
137	14.84	1.05	5.77
138	15.09	1.95	24.75
139	5.33	.24	15.38
141	13.49	1.58	15.49
143	4.09	1.91	15.38
144	2.53	11.54	13.70
149	3.62	6.35	14.78
153	3.55	5.24	18.81
166	4.57	.28	15.38
167	19.75	.49	2.08
168	21.93	.32	2.86
169	23.21	.24	3.64
170	22.20	.62	2.21
171	18.18	1.67	.33
173	17.24	.93	.62
174	10.65	2.16	.87
175	18.70	.60	2.65
176	13.52	.71	3.13

ABBREVIATIONS

authig.	authigenic
biot.	biotite
bl.-gr. hb.	blue-green hornblende
cpx.	clinopyroxene
dol.	dolomite
enstat.	enstatite
garn.	garnet
gr.-br. hb.	green-brown hornblende
hypersth.	hypersthene
mag. + ilm.	magnetite and ilmenite
px.	pyroxene
staur.	staurolite
tourm.	tourmaline
zirc.	zircon

DRILLHOLE 75-02

Sample no.	bl-gr. hb.	gr-br. hb.	pink garn.	orange garn.	authig. pyrite	mag + ilm.	epidote	siderite	altered px.	hypersth.	enstat.	cpx.	twin staur.	gold staur.	rutile	tourm.	biot.	zirc.	dol.	picotite	topaz	indicolite	spinel
125	37		5		6	13	3	11	14	tr	2	2	3	tr		tr			tr		1		
127	30		6	1	3	18	5	10	14	1	2	2	4	tr	tr	tr					1		
131	31	3	4	1	4	10	2	16	12	7	4	3	3			1		tr		tr			
135	23	tr	10	1	4	20	2	9	16	1	3	4	4			tr			tr		1		
137	32		8		2	18	3	12	14	tr	3	1	6			1			tr		1		
138	40		9	tr	3	7	5	7	10	2	2	2	1	tr			7	tr	2		1		
139	30	3	13	tr	2	16	5	6	15	3	2	2		tr	tr			tr	tr		tr		
141	35	4	10	tr	1	13	3	5	14	4	5	3	1	tr		1		tr	1		1		
143	23	1	10		7	15	4	10	15	4	2	4	3		tr	tr			1				
144	19	2	12		5	19	4	6	14	2	5	7		tr					2				
149	22	1	12	2	6	11	4	10	16	9	4	3			tr					tr			
153	18		11	1	21	10	5	5	9	7	3	6	1	1	1				2				
166	tr		5		75	8		tr	7		1								3				
167		1	33	3	52	4	tr		2					1		tr			2				
168	tr		60	5	21	5	1		1					3		1				tr			
169	1		56	5	28	7	1		4					2		1			tr				
170	tr		41	5	35	3	1		2					3	tr	1				tr			
171			15	8	67	2	1		2					tr		tr			1				
173	tr		31	8	49	3			2		tr			2		tr							
174			27	5	63	1	tr		tr					2		1							
175			28	6	59	2	tr		tr					3		tr			1				
176	1		38	4	45	2	1		2	1				4		tr			tr				

DRILLHOLE 75-06

Sample no.	bl-gr. hb.	gr-br. hb.	pink garn.	orange garn.	authig. pyrite	mag + ilm.	epidote	siderite	altered px.	hypersth.	enstat.	cpx.	twin staur.	gold staur.	rutile	tourm.	biot.	zirc.	dol.	picotite	topaz	indicolite	spinel
57	43		14	tr	3	2	3	tr	15	5	5	5		tr	tr	tr	tr	tr	2				
59	44	tr	18	1	3	3	4	1	13	5	3	4			1	tr	tr		tr				
61	43	1	13	tr	3	5	5	2	13	7	2	4		tr	tr				2	tr			
63	31	4	3		4	3	2	2	21	6	2	6			tr	tr	14	tr					tr
67	39	1	15		6	9	3	2	14	4	4	2	2				tr	tr	2				
75	48	3	10		4	4	3	2	10	2	3	4	1		1		4						
76	35		13		7	8	3	8	10	2	4	3	3		2	tr	tr						
78	34		11		7	6	4	7	8	5	4	5	4		1	tr	tr		2				
82	29	1	13	tr	13	5	1	7	9	6	3	4	2		1	tr	tr	tr	1				
86	27		12		16	6	3	9	8	5	1	5	6		1		tr	tr	1				tr
87	20		13		29	7	3	8	8	2	2	2	5	1		tr			tr				
88	30	tr	16	tr	12	8	3	5	8	4	4	4	3					tr	tr				
89	25		17	1	14	8	4	4	12	3	2	4	4	tr		tr		tr	tr				tr
91	26		10		17	7	3	8	14	1	1	6	6		1				tr	tr	1		
93	17		15	2	34	5	2	6	9	2	1	3	3		tr					tr	tr		
95	19		14	tr	41	4	2	6	7	2	tr	3	2					tr			tr		
97	30	2	15	1	24	3	3	4	10	1	2	1	1		tr			tr			1		
99	21	tr	19	tr	33	5	1	4	5	3	1	2	3	tr	tr		tr		tr		tr		
101	34	2	15	tr	24	3	3	2	7	3	tr	3	2		tr	tr			tr				
103	40	2	14		7	3	5	4	11	3	tr	4	5		tr		tr		tr		tr		
105	23		12	1	40	3	3	4	6	2	tr	2	4		tr	tr			tr				
107	27	tr	9		29	4	5	7	9	4	1	2	3			tr					tr		
109	20	tr	11		46	3	1	4	7	4		2	3										
111	26		12		32	4	4	4	6	4		1	5		tr				tr		tr		
113	17		15		42	4	2	4	6	2		2	3		tr	tr			tr				
115	23	tr	14	tr	21	10	3	7	7	4	2	4	1	tr				tr			tr		
117	28		12	tr	26	5	4	5	9	3		2	4	tr			tr		tr	1			
118	22		9	tr	39	3	3	5	10	3		2	3	tr			tr					tr	
119	26		14		32	4	3	5	6	2	tr	2	5		tr		tr		tr			tr	
121	18		14	tr	36	2	2	5	9	5		4	5				tr		tr				
123	23	tr	9		31	3	2	6	9	4	1	4	7		tr	tr							
125	23		19		26	7	3	4	8	2		1	7		tr								
127	25	1	12		39	3	2	4	5	2		1	6	tr					tr				
129	19	1	9		49	3	1	5	4	2		2	1	tr			tr		2		1	tr	
132	15	tr	18		45	5	2	4	5	2		tr	2		tr				tr		tr		
134	32	2	19		18	4	4	2	7	3	3	3	2		tr	3			tr				
138	25		9		33	5	2	5	10	3		4	3			tr					1		

APPENDIX C

Carbonate Analyses
Note: All values are percentages
percentage of clay material analysed.
dol. - dolomite
calc. - calcite

DRILLHOLE 75-02

Sample No.	grams used	Dol. %	Calc. %	Total %	Calc. Dol.
125	1.70	7.50	4.06	11.56	0.542
	1.70	8.20	4.04	12.24	0.492
127	1.70	8.20	5.96	14.16	0.727
	1.70	8.89	5.21	14 10	0.587
131	0.850	8.46	5.94	14.50	0.705
	0.850	9.36	4.43	13.84	0.478
	1.70	9.60	7.16	16.76	0.746
135	1.70	8.89	8.87	17.76	0.998
	1.70	8.89	8.88	17.77	0.998
137	1.70	8.85	8.41	17.26	0.950
	1.70	8.60	8.21	16.81	0.954
138	1.70	2.27	1.81	4.08	0.797
	1.70	2.51	2.00	4.51	0.796
139	0.850	6.00	5.60	11.60	0.933
	0.850	6.00	5.60	11.60	0.933
141	1.70	10.40	6.99	17.39	0.671
	1.70	10.19	7.00	17.19	0.687
143	0.850	9.27	4.42	13.69	0.477
	0.850	8.77	5.37	14.14	0.612
144	0.2125	5.96	13.18	19.14	2.211
149	0.2125	2.26	4.73	6.99	2.090
	0.425	3.31	5.71	9.02	1.730
153	0.850	5.00	38.60	43.60	7.720
	0.850	5.55	37.50	43.05	6.757
166	1.70	10.57	12.67	23.24	1.198
	1.70	10.57	13.18	23.75	1.247
167	1.70	6.66	17.02	23.68	2.558
	1.70	6.66	17.02	23.68	2.558
168	0.425	3.28	24.88	28.16	7.585
	0.425	2.26	25.84	28.10	11.434

DRILLHOLE 75-02

Sample No.	grams used	Dol. %	Calc. %	Total %	Calc. Dol.
169	0.425	3.28	33.70	36.98	10.274
	0.425	2.26	35.50	37.76	15.708
170	0.850	1.34	15.09	16.43	11.250
	0.850	2.77	13.86	16.63	5.000
171	1.70	0.91	31.50	32.41	34.623
	1.70	1.12	31.28	32.40	27.923
173	0.850	2.66	32.38	35.04	12.173
	0.850	2.66	33.40	36.06	12.556
174	0.425	6.24	48.12	54.36	7.712
	0.425	5.32	50.68	56.00	9.526
175	1.70	1.56	38.25	39.81	24.519
	1.70	1.12	38.30	39.42	34.196
176	0.850	1.84	53.83	55.67	29.255
	0.850	2.66	53.64	56.30	20.165

DRILLHOLE 75-03

Sample No.	grams used	Dol. %	Calc. %	Total %	Calc. Dol.
165	0.2125	9.93	13.45	23.38	1.354
167	—				
169	0.2125	13.78	7.30	21.08	0.530
171	0.2125	4.19	3.77	7.96	0.900
178	0.2125	2.30	3.89	6.14	1.670
185	0.2125	6.08	29.27	35.35	4.814
	0.2125	6.08	29.27	35.35	4.814
189	0.850	5.63	24.32	29.95	4.320
	0.850	5.10	22.73	27.83	4.467

DRILLHOLE 75-05

Sample No.	grams used	Dol. %	Calc. %	Total %	Calc. Dol.
26	0.2125	9.80	11.35	21.15	1.250
27	—				
28	0.2125	22.97	10.88	33.85	0.474
39	0.2125	2.27	1.80	4.07	0.793
	0.2125	2.27	3.77	6.04	1.661
78	—				
98	0.2125	2.27	1.80	4.07	0.793
	0.2125	1.34	3.80	5.14	2.836
102	0.425	1.37	0.80	2.17	0.584
	0.425	1.37	0.80	2.17	0.584

OUTCROP SAMPLES

	grams used	Dol. %	Calc. %	Total %	Calc. Dol.
Adam Crk. Pleist.	0.425	2.27	1.81	4.08	0.797
	1.70	2.07	1.80	3.37	0.677
Adam Crk. Cret.	0.850	0.72	0.40	1.12	0.555
	1.70	0.92	0.62	1.53	0.663
Missin. Cret.	0.850	0.72	0.60	1.32	0.833
	1.70	0.71	0.41	1.12	0.555

DRILLHOLE 75-06

Sample No.	grams used	Dol. %	Calc. %	Total %	Calc. Dol.
57	1.70	16.57	17.25	34.82	1.041
	1.70	16.93	16.89	33.28	0.990
59	1.70	15.92	17.11	33.03	1.075
	1.70	17.05	16.12	33.12	0.945
61	0.850	20.74	15.32	36.06	0.739
	0.850	19.20	16.85	36.05	0.878
63	1.70	9.67	4.20	13.87	0.434
	1.70	9.25	5.86	15.11	0.630
67	1.70	12.21	5.24	17.48	0.428
	1.70	12.00	5.76	17.76	0.480
75	1.70	10.34	5.28	16.12	0.487
	1.70	10.33	5.30	15.63	0.513

DRILLHOLE 75-06

Sample No.	grams used	Dol. %	Calc. %	Total %	Calc. Dol.
76	1.70	10.13	4.77	14.90	0.471
	1.70	9.62	5.10	14.72	0.530
78	1.70	10.13	5.29	15.42	0.523
	1.70	10.13	5.28	15.41	0.521
82	1.70	10.18	5.62	15.80	0.552
	1.70	9.46	5.85	15.31	0.618
86	1.70	10.13	4.68	14.81	0.462
	1.70	9.61	5.22	14.83	0.543
87	1.70	9.83	4.95	14.78	0.504
	1.70	9.83	4.68	14.51	0.476
88	1.70	9.83	4.68	14.51	0.476
	1.70	9.61	5.49	15.10	0.571
89	1.70	11.28	5.15	16.43	0.457
	1.70	11.28	5.15	16.43	0.457
91	1.70	10.66	4.60	15.26	0.432
	1.70	10.45	5.12	15.57	0.490
93	1.70	13.48	5.23	18.71	0.388
	1.70	12.32	6.00	18.32	0.487
95	—				
97	0.2125	16.56	14.95	31.51	0.902
99	—				
101	0.425	14.08	8.72	22.30	0.619
	0.425	14.92	8.68	23.60	0.582
103	0.2125	14.72	10.32	25.04	0.701
	0.2125	20.00	10.08	30.08	0.504
105	0.2125	8.96	8.88	17.84	0.991
107	0.425	9.96	12.92	23.88	1.290
	0.425	11.08	12.88	23.96	1.163
109	0.2125	14.72	19.28	34.00	1.310
111	—				
113	—				
115	—				
117	—				
118	0.2125	18.08	35.76	53.84	1.978
119	—				
121	—				
123	0.2125	20.00	24.16	44.16	1.208
125	0.2125	14.72	12.00	26.72	0.815
	0.2125	14.72	12.00	26.72	0.815
127	0.2125	14.80	37.60	52.40	2.541
	0.2125	16.40	37.44	53.84	2.283
129	0.2125	12.48	28.48	40.96	2.283
132	0.2125	16.40	17.76	34.16	1.083
	0.2125	16.40	17.76	34.16	1.083
134	1.70	8.94	5.74	14.68	0.648
	1.70	9.80	6.65	16.45	0.678
138	0.425	13.96	28.20	42.16	2.020
	0.425	13.12	25.32	38.44	1.930

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Mesozoic Palynology of the Moose River Basin

by

Geoffrey Norris[1]

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ABSTRACT

Dispersed spore-pollen assemblages in fine-grained clastic sediments and coals from the Mesozoic of the Moose River Basin are listed and illustrated in part. Palynofloras from the Middle Jurassic Mistuskwia Beds in the subsurface of the central part of the basin are dominated by coniferous pollen and are comparable with the Middle Jurassic palynofloras of the western Canadian plains. Palynofloral assemblages from the Mattagami Formation are more diverse with many pteridophyte species represented. Approximately 160 spore-pollen species from the Mattagami Formation are used to delimit four interval zones spanning the Middle and Upper Albian. Spores and pollen from the lignites at Onakawana correlate most closely with the early Middle Albian Reticulatasporites-Concavissimisporites Zone. This zone has also been identified in the subsurface of the southern part of the Moose River Basin. Mattagami palynofloras correlate with those from the Potomac Group of the Atlantic Coastal Plain, the Swan River Group of Saskatchewan and Manitoba, the upper Mannville Group and lower Colorado Group of central Alberta, the Loon River, Peace River, and lower Shaftesbury Formations of northwestern Alberta, and the Logan Canyon Formation of offshore eastern Canada. Mattagami assemblages are entirely non-marine but recycled Devonian acritarchs are present in some horizons.

INTRODUCTION

Stratigraphic correlation and age determinations of nonmarine Mesozoic sediments of the Moose River Basin have been made possible using spores and pollen (palynomorphs) which are abundant in most sediments. Megaplant remains were used for initial age determinations in the earlier studies of the Mattagami Formation (see Bell 1928; Radforth 1958; Verma *et al.* 1978) but, unlike plant microfossils, they are relatively rare and sporadic in occurrence. Thus, precise correlation was not possible.

Palynology is now a routine procedure in stratigraphic studies of both surface and sub-surface material. Industrial applications of palynology are widespread in petroleum exploration, and as early as the 1920s the coal industry was utilizing spore-pollen work for correlation. Studies in Mesozoic palynology have proliferated since the 1950s with the increasing attention paid, in particular, to offshore as well as onshore basins for petroleum development. In North America, the following published palynologic studies are particularly relevant to the Mesozoic of the Moose River Basin (Table 4.1)

In addition to the above, numerous smaller contributions have made significant additions to knowledge of the biostratigraphy and taxonomy of palynomorphs from specific North American horizons and areas, some of which will be referred to below. Major works on the taxonomy and stratigraphy of spores and pollen from other parts of the world also have considerable relevance to the Ontario Mesozoic in view of the cosmopolitan nature of some elements of the flora.

TABLE 4.1 | CRETACEOUS PALYNOFLORAL STUDIES.

CRETACEOUS PALYNOFLORAL STUDIES.

Author	Area	Age
Pocock 1962	western Canada	Upper Jurassic-Lower Cretaceous
Brenner 1963	eastern USA	Lower Cretaceous
Singh 1964	Alberta	Lower Cretaceous
Norris 1967	Alberta	Lower Cretaceous
Singh 1971	Alberta	Lower and Upper Cretaceous
Pocock 1970, 1972	western and northern Canada	Jurassic
Williams 1975	offshore eastern Canada	Jurassic-Cretaceous
Williams and Brideaux 1975	Atlantic continental margin	Cretaceous
Brideaux and McIntyre 1975	northern Canada	Lower Cretaceous
Doyle and Robbins 1977	eastern USA	Cretaceous

DESCRIPTION OF PALYNOFLORAL ASSEMBLAGES

Middle Jurassic

Middle Jurassic palynofloral assemblages have been reported by Norris (1977) from the top two-thirds of a sequence of 16 m of varicoloured clays and thin unconsolidated quartz sand horizons, informally termed the Mistuskwia Beds by Telford *et al.* (1975) (see also Telford, this report). These assemblages have only been reported from one locality to date; Ontario Geological Survey drillhole 75-03 (50°41'35''N, 82°48'08''W). Here, the Mistuskwia Beds are overlain by thick Pleistocene till, sand and gravel; their relationship to the Mattagami Formation (Lower Cretaceous) is poorly known.

The assemblages comprise more than two dozen species but are dominated by only a few bisaccate species (*Alisporites bilateralis* Rouse, *Pteruchipollenites microsaccus* Couper, *Podocarpidites convolutus* Pocock) and species of *Callialasporites* and *Cerebropollenites*.

Other elements of the assemblage are listed below and illustrated in Norris(1977) with the ranges of stratigraphically-restricted species indicated:

Alisporites bilateralis Rouse
Apiculatisporis sp.
Araucariacites australis Cookson
Araucariacites sp.
Callialasporites crenulatus Pocock (Middle-Upper Jurassic)
Callialasporites dampieri (Balme) Dev (Lower Jurassic-Lower Cretaceous)
Callialasporites sp. cf. C. *segmentatus* (Balme) Dev
Callialasporites trilobatus (Balme) Dev (Lower Jurassic-Lower Cretaceous)
Callialasporites turbatus (Balme) Schulz (Lower-Middle Jurassic)
Cerebropollenites carlylensis Pocock (Middle-Upper Jurassic)
Classopollis minor Pocock (Middle Jurassic—higher Cretaceous occurrences are probably due to recycling)
Classopollis sp.
Classopollis torosus (Reissinger) Balme
Cyathidites minor Couper
Deltoidospora hallei Miner
Exesipollenites tumulus Balme
Kraueselisporites sp.
Leptolepidites paverus Levet-Carette (Middle Jurassic)
Perinopollenites elatoides Couper
Perinopollenites sp.
Podocarpidites convolutus Pocock (Middle-Upper Jurassic)
Spheripollenites scabratus Couper (Middle Jurassic-Lower Cretaceous)
Pteruchipollenites microsaccus Couper
Spheripollenites psilatus Couper
Taxodiaceaepollenites hiatus (Potonie) Kremp

These assemblages were compared by Norris (1977) with palynofloras described from western Canada by Pocock (1970). The greatest number of common species occurs in the Upper Gravelbourg of Alberta and Saskatchewan,

floras from which were stated by Pocock (1970) to indicate an early Bajocian age. Comparisons of the Mistuskwia assemblages with those from the Shaunavon and Sawtooth Formations of the southern Canadian plains are also possible. These formations were dated by Pocock as Bajocian-Bathonian although Brooke and Braun (1972) indicate that the Shaunavon Formation may range from Bajocian to Callovian in age. The western Canadian Middle Jurassic palynofloras are noticeably distinct from those of the Moose River Basin in having more diverse pteridophyte species, so far unreported from Ontario. Comparisons with the Middle Jurassic of northwest Europe can also be made, but here again the European assemblages have a greater diversity of pteridophyte spores.

Aptian-Lower Albian

Palynofloras listed by Hopkins and Sweet (1976) from surface and subsurface sections of the Mattagami Formation were assessed by them (p. 59) as "probably not younger than Early Albian, nor older than Aptian." Megaspores discussed in the same work suggested an Early Albian age. This study was evidently a reconnaissance, and the results were a preliminary assessment of palynofloras obtained from the total Mattagami section (approximately 43 m) penetrated by four drillholes, and from samples of the lignite stockpile at the Onakawana lignite pit. Not all species were identified accurately. Illustrations of pteridophyte spores indicate the presence of Middle and Upper Albian species. Consequently, Hopkins and Sweet's age assignment is rejected and their results will be discussed below.

Middle Albian

Palynofloras of this age have been obtained from a number of different sources and will be discussed in this context.

OPERATION WINISK BOREHOLES

These drillholes were put down between Onakawana and the Mattagami River, and penetrated two lignite seams. Spores and pollen obtained from the lignite and other horizons in the Mattagami Formation (36 miospore species, 10 megaspore species) were listed and illustrated by Hopkins and Sweet (1976)[1].
Their results were evidently preliminary in view of the large fraction of species left in open nomenclature. Their preferred age assignment of Early Albian is

[1]Longitudes listed by Hopkins and Sweet (1976) for these drillholes are incorrect. Correct location of the holes are as follows:
#68-38 — 50°36'00"N, 81°31'12"W #68-42—53°35'36"N, 81°30'12"W
#68-39 — 50°35'48"N, 81°30'42"W #68-43—50°35'26"N, 81°28'56"W

probably in error because of the presence (to judge from their illustrations) of the following Middle-Upper Albian species:

Cicatricosisporites spiralis Singh (their Plate 9, fig. 12) - Middle Albian
Appendicisporites unicus (Markova) Singh (their Plate 9, fig. 13) - Middle Albian-Cenomanian

Hopkins and Sweet (1976, p.56) note that the above species are relatively common to abundant in all samples, suggesting an age of Middle Albian at the oldest for the entire Mattagami Formation penetrated in the Operation Winisk drillholes. In view of the similarity of these miospore floras with those obtained from the Ontario Geological Survey drillholes, species are listed only at this point and discussion deferred to a later section:
Alisporites sp.
Appendicisporites spp.
Baculatisporites comaumensis (Cookson) Potonié
Cerebropollenites mesozoicus (Couper) Nilsson
Chomotriletes fragilis Pocock
Cicatricosisporites spp.
Cingutriletes clavus (Balme) Dettmann
Classopollis torosus (Reissinger) Balme
Converrucosisporites sp.
Cycadopites sp. cf. C. scabratus Stanley
Cyathidites minor Couper
Densoisporites sp.
Eucommiidites troedssoni Erdtman
Gleicheniidites senonicus Ross
Glyptostrobus sp.
Impardecispora apiverrucata (Couper) Venkatachala *et al.*
Inaperturopollenites sp.
Kuylisporites lunaris Cookson and Dettmann
Laevigatosporites sp.
Laricoidites sp. cf. *L. magnus* (Potonié) Potonié
Lycopodiumsporites spp.
Lygodium sp. cf. *L. reticulosporites* Rouse
Osmundacidites wellmanii Couper
Perinopollenites sp. cf. *P. elatoides* Couper
cf. *Phyllocladidites* sp.
Podocarpidites sp.
?Protopicea sp.
cf. *Sciadopitys* sp.
Sestrosporites pseudoalveolatus (Couper) Dettmann
Stereisporites antiquasporites (Wilson and Webster) Dettmann
Taxodium sp.
Impardecispora apiverrucata(Couper) Venkatachala *et al.*
Vitreisporites pallidus (Reissinger) Nilsson

The megaspores, however, showed significantly different distribution patterns. The following megaspores were identified by Hopkins and Sweet (1976):
Arcellites disciformis Miner emend. Ellis and Tschudy
Arcellites incipens Singh
Bacutriletes sp. cf. *B. onodios* (Harris) Hopkins and Sweet

Erlansonisporites sparassis (Murray) Potonié
Minerisporites sp. cf. *M. alius* Batten
Paxillitriletes sp. cf. *P. fairlightensis* (Batten) Hall and Nicholson
Spermatites sp. cf. *S. ellipticus* Miner
Tenellisporites spinatus Peake *in* Hall and Peake
Triletes lanaris Vangerow
Triletes sp.

Megaspores were used to differentiate the two lignite seams principally on the presence or dominance (the latter indicated*) of the following:
Lower Seam: *Arcellites disciformis**
*Arcellites incipiens**
Bacutriletes sp. cf. *B. onodios**
Paxillitriletes sp. cf. *P. fairlightensis*
Upper Seam: *Erlansonisporites sparassis**
Triletes spp.

Arguments were presented by Hopkins and Sweet (1976) to suggest that the lower lignite was deposited in a swamp environment whereas the upper lignite represents dryer, more terrestrial conditions.

Megaspore abundance in samples from the Onakawana lignite stockpile suggest a correlation of this material with the lower seam penetrated by the Winisk drillholes.

ONAKAWANA LIGNITE

Hopkins and Sweet (1976) indicated that spore-pollen assemblages extracted from samples taken from the Onakawana lignite stockpile were, in general, similar to those described from the Winisk drillholes but were additionally characterized by the following:
Ephedra sp.
Schizosporis sp.
Spheripollenites sp.
Clavatipollenites sp. cf. *C. hughesi* Couper

Telford *et al.* (1975) provided the following species list from the Onakawana stockpile (species in informal nomenclature are preceded by a unique number listed in Telford et al., 1975; some species are illustrated in this report as indicated by reference to figure numbers):
Alisporites bilateralis Rouse (Plate 9, fig.18, 19)
Alisporites grandis (Cookson) Dettmann (Plate 9, fig. 9,10)
Appendicisporites unicus (Markova) Singh (Plate 4, fig. 23, 24)
Biretisporites potoniei Delcourt and Sprumont (Plate 1, fig.14-16)
Cedripites sp. cf. *C. cretaceus* Pocock (Plate 10, fig. 1-3)
Cedripites cretaceus Pocock (Plate 9, fig. 16)
Cicatricosisporites hallei Delcourt and Sprumont (Plate 4, fig.1-2)
Crybelosporites brenneri Playford (Plate 6, fig. 18-20)
Cyathidites minor Couper (Plate 1, fig. 7)
Gleicheniidites senonicus Ross (Plate 6, fig. 8)
Lycopodiumsporites austroclavatidites (Cookson) Potonié

Microreticulatisporites uniformis Singh (Plate 2, fig.18-20)
Osmundacidites wellmanii Couper (Plate 1, fig. 17)
Perinopollenites elatoides Couper (Plate 8, fig. 4, 5)
Podocarpidites radiatus Brenner (Plate 9, fig. 14, 15)
492 *Pteruchipollenites-2* (Plate 10, fig. 4-6)
499 *Reticulatasporites-1* (Plate 11, fig. 19-27)
Stereisporites antiquasporites (Wilson and Webster) Dettman (Plate 1, fig. 1, 2)
Taurocusporites segmentatus Stover (Plate 3, fig. 11)
Taxodiaceaepollenites hiatus (Potonié) Kremp (Plate 7, fig. 26, 27)
Vitreisporites pallidus (Reissinger) Potonié (Plate 8, fig. 35)

Similarities are evident with palynofloras from the Middle Albian Loon River and Peace River Formations of northern Alberta (Singh 1971), the upper part of the Manville Group of central Alberta (Singh 1964), and the Swan River Group of Manitoba and Saskatchewan (Playford 1971). Significantly, tricolpate pollen is absent from the lignite assemblage. Dicotyledonous pollen first appears in Alberta in the upper Middle Albian with very rare occurrences of one angiosperm species slightly lower (Singh 1971). In the Atlantic Coastal Plain, tricolpate pollen appears in the Potomac Group of Maryland and Delaware near the estimated Lower/Middle Albian contact (Doyle and Robbins 1977).

Angiosperm range zones are now known to be highly diachronous across paleolatitudes, generally appearing earlier in lower latitudes (Doyle 1977). Paleocontinental reconstructions (Smith and Briden 1977, Maps 7, 8, 20, and 21) indicate a paleolatitude for the Moose River Basin (ca. 40°N) during the mid-Cretaceous, approximately midway between Alberta (ca. 55°N) and Maryland and Delaware (ca. 30°N) suggesting that dicotyledonous angiosperm pollen might be expected to first appear during the medial portion of the Middle Albian in this area. Thus the lack of dicotyledonous tricolpate angiosperm pollen in the Onakawana lignite is taken to indicate an early Middle Albian age in the light of present understanding of early angiosperm evolution and radiation.

OGS DRILLHOLES 75-05 AND 75-06

Palynologic analyses of samples from these drillholes were presented in preliminary form by Telford *et al.* (1975). The assemblages are nonmarine but recycled Devonian acritarchs occur rarely at some horizons (Plate 12, figs. 8-9). Three interval zones (sensu Hedberg 1976) are recognized as follows, in ascending order.

Reticulatasporites-Concavissimisporites Interval Zone

This zone is present from 127 to 135 m in drillhole 75-06 (see Figure 2.8). It is characterized by the frequent occurrence of the following:
Alisporites bilateralis Rouse (Plate 9, fig. 18, 19)
Alisporites grandis (Cookson) Dettmann (Plate 9, fig. 9, 10)
Araucariacites australis Cookson

Biretisporites potoniei Delcourt and Sprumont (Plate 1, fig. 14-16)
Cerebropollenites mesozoicus (Couper) Nilsson (Plate 11,fig. 1)
Cicatricosisporites hallei Delcourt and Sprumont (Plate 4, fig. 1-3)
Cyathidites minor Couper (Plate 1, fig. 7)
496 *Gleicheniidites-1* (Plate 6, fig. 1-7)
Gleicheniidites senonicus Ross (Plate 6, fig. 8)
Laevigatosporites ovatus Wilson and Webster (Plate 7, fig. 25)
Podocarpidites multisimus (Bolchovitina) Pocock (Plate 9, fig. 17, 20)
499 *Reticulatasporites-1* (Plate 11, fig. 19-27)
Stereisporites antiquasporites (Wilson and Webster) Dettmann (Plate 1, fig. 1, 2)
Taxodiaceaepollenites hiatus (Potonié) Kremp (Plate 7, fig.26, 27)

Less frequent but characteristic species in this zone include:
Aequitriradites spinulosus (Cookson and Dettmann) (Plate 6, fig. 26, 27; Plate 7, fig. 1-6)
Appendicisporites erdtmanii Pocock (Plate 4, fig. 20)
Appendicisporites problematicus (Burger) Singh (Plate 4, fig.21.22)
Baculatisporites comaumensis (Cookson) Potonié (Plate 1, fig. 19)
Cedripites canadensis Pocock (Plate 8, fig. 33, 34)
Cedripites sp. cf. *C. cretaceus* Pocock (Plate 10, fig. 1-3)
Cedripites cretaceus Pocock (Plate 9, fig. 16)
441 *Cicatricosisporites-1* (Plate 3, fig. 19-22)
503 *Cicatricosisporites-2* (Plate 3, fig. 26-29)
Cicatricosisporites australis (Cookson) Potonié (Plate 3, fig. 17, 18)
Cicatricosisporites sp. cf. *C. ludbrooki* Dettmann (Plate 3, fig. 30, 31)
Cicatricosisporites hughesi Dettmann (Plate 3, fig. 16)
Cicatricosisporites orbiculatus Singh (Plate 3, fig. 23)
494 *Concavissimisporites-1* (Plate 2, fig. 1,2)
Concavissimisporites sp. cf. *C. punctatus* (Delcourt and Sprumont) Brenner (Plate 1, fig. 10)
Concavissimisporites punctatus (Delcourt and Sprumont) (Brenner Plate 1, fig. 9)
Converrucosisporites variverrucatus (Couper) Norris (Plate 1, fig. 18)
Cyathidites australis Couper
Eucommiidites minor Groot and Penny (Plate 8, fig. 16-19)
Foraminisporis asymmetricus (Cookson and Dettman) Dettman (Plate 5, fig. 25, 26)
Impardecispora sp. cf. *I. marylandenis* (Brenner) Srivastava (Plate 5, fig. 9)
Impardecispora tribotrys (Dettmann) Venkatachala *et al.* (Plate 5, fig. 21, 22)
Impardecispora trioreticulosa (Cookson and Dettmann) Venkatachala *et al.* (Plate 5, fig. 19)
Klukisporites sp. cf. *K. pseudoreticulatus* Couper (Plate 3, fig. 4)
Microreticulatisporites uniformis Singh (Plate 2, fig. 18, 19)
Osmundacidites wellmanii Couper (Plate 1, fig. 17)
Parvisaccites radiatus (Plate 9, fig. 3-5)
Perinopollenites elatoides Couper (Plate 8, fig. 10, 11)
Platysaccus megasaccus Brenner (Plate 10, fig. 7, 8)
Podocarpidites radiatus Brenner (Plate 9, fig. 14, 15)
492 *Pteruchipollenites-2* (Plate 10, fig. 4-6)

Schizosporis reticulatus Cookson and Dettmann (Plate 12, fig. 5)
Sestrosporites pseudoalveolatus (Couper) Dettmann (Plate 2, fig. 10)
Todisporites major Couper (Plate 1, fig. 8)
497 *Tripartina-2* (Plate 1, fig. 6)
Triporoletes radiatus (Dettmann) Playford (Plate 7, fig. 7)
Vitreisporites pallidus (Reissinger) Potonié (Plate 8, fig. 35)

The absence of dicotyledonous tricolpate angiosperm pollen from this zone is noteworthy, as is the similarity in palynofloral composition to the Onakawana lignite. A general resemblance to Middle Albian palynofloras from Alberta (Singh 1964; 1971) is evident. In particular, the presence of *Microreticulatisporites uniformis*, *Impardecispora tribotrys*, and 499 *Reticulatasporites-1* (= *Callialasporites* sp. of Singh 1971) collectively indicates a Middle Albian age, matching in part assemblages described from the Loon River Formation of Alberta which also contain a lower Middle Albian *Subarcthoplites* fauna (Singh 1971). The essentially non-marine floras from the upper part of the Mannville Group of central Alberta also contain some of the above species and have also been correlated with the lower Middle Albian (Singh 1964). *Cicatricosisporites orbiculatus* occurs rarely in drillhole 75-06 and has only been reported previously as a single occurrence at the base of the Ellerslie Member (McMurray Formation) in the lower part of the Mannville Group of Alberta (Singh 1964) and questionably assigned an Aptian or possibly early Albian age.

Thus the flora is believed to be early Middle Albian in age, which accords with a similar age for the Onakawana lignite dated previously on the basis of early angiosperm radiation patterns. The Onakawana lignite palynoflora is less diverse, however, which is the result of local over-representation of swamp species excluding elements of the regional flora (Chaloner and Muir 1968).

Tigrisporites-Trilobosporites humilis Interval Zone

This zone is present between 44 m and 54 m in drillhole 75-05 (see figure 2.8). It may also be represented by impoverished palynofloras in drillhole 75-06 above 124 m. Many specimens from lower horizons range into the higher zones. Discussion will be confined to stratigraphically restricted species characteristic of the zone.

The *Tigrisporites-T. humilis* zone is characterized by the following species with local range tops restricted to the interval:
Acanthotriletes sp. cf. *A. varispinosus* Pocock (Plate 1, fig. 23)
Aequitriradites spinulosus (Cookson and Dettmann) Cookson and Dettmann (Plate 6, fig. 26, 27, Plate 7, fig. 1-6)
Appendicisporites bilateralis Singh (Plate 4, fig. 15-19)
Appendicisporites crimensis (Bolchovitina) Pocock (Plate 4, fig. 14)
Appendicisporites sp. cf. *A. macalesteri* Pocock (Plate 4, fig. 9, 10)
Appendicisporites spinosus Pocock (Plate 4, fig. 12, 13)
477 *Baculatisporites-1* (Plate 1, fig. 12, 13)
483 *Baculatisporites-2* (Plate 1, fig. 20-22)
Baculatisporites comaumensis (Cookson) Potonié (Plate 1, fig. 19)
Chomotriletes fragilis Pocock (Plate 11, fig. 28)

Cicatricosisporites patapscoensis Brenner
Cicatricosisporites potomacensis Brenner (Plate 3, fig. 13, 14)
Circulina parva Brenner (Plate 8, fig. 7)
Classopollis torosus (Reissinger) Balme (Plate 8, fig. 6)
Converrucosisporites sp. cf. *C. platyverrucosus* Brenner (Plate 1, fig. 24)
469 *Cooksonites-1* (Plate 7, fig. 12, 13, 15, 16)
489 *Coptospora-1* (Plate 7, fig. 8-11)
Costatoperforosporites fistulosus Deak (Plate 4, fig. 4)
Cyathidites australis Couper
Deltoidospora juncta (Kara-Murza) Singh (Plate 1, fig. 5)
Distaltriangulisporites reticulatus Singh
487 *Foraminisporis-1* (Plate 4, fig. 25)
Foveotriletes subtriangularis Brenner (Plate 2, fig. 9)
Klukisporites foveolatus Pocock (Plate 2, fig. 32)
Lophotriletes babsae (Brenner) Singh (Plate 2, fig. 5-7)
Ornamentifera echinata (Bolchovitina) Bolchovitina (Plate 6, fig. 12)
Osmundacidites wellmanii Couper (Plate 1, fig. 17)
479 *Parvisaccites-2* (Plate 9, fig. 1, 2)
476 *Perotrilites-1* (Plate 6, fig. 14)
Podocarpidites multisimus (Bolchovitina) Pocock (Plate 9, fig. 17)
471 *Pristinuspollenites-3* (Plate 9, fig. 8)
474 *Pteruchipollenites-1* (Plate 9, fig. 6, 7)
492 *Pteruchipollenites-2* (Plate 10, fig. 4-6)
Reticulisporites elongatus Singh (Plate 2, fig. 8)
Rouseia sp. cf. *R. geranioides* (Couper) Srivastava (Plate 11, fig. 4, 5)
Rugubivesiculites rugosus Pierce
Schizosporis grandis Pocock (Plate 11, fig. 29)
Taurocusporites sp. cf. *T. segmentatus* Stover (Plate 3, fig.5)
465 *Tigrisporites-1* (Plate 2, fig. 12)
Tigrisporites reticulatus Singh (Plate 2, fig. 28-31)
Tigrisporites scurrandus Norris (Plate 2, fig. 24-27)
Tigrisporites sp. B. Singh (Plate 2, fig. 21, 22)
473 *Tricolpites-1* (Plate 11, fig. 15-18)
486 *Trilobosporites-2* (Plate 5, fig. 1, 2)
Trilobosporites hannonicus Delcourt and Sprumont (Plate 4, fig. 26)
Trilobosporites humilis Delcourt and Sprumont (Plate 5, fig. 3-8)
Triporoletes radiatus (Dettmann) Playford (Plate 7, fig. 7)
Triporoletes reticulatus (pocock) Playford (Plate 6, fig. 21-25)
482 *Uvaesporites-1* (Plate 5, fig. 23, 24)
480 *Vitreisporites-1* (Plate 9, fig. 21-23)

Closest comparisons of this flora are with the Upper Peace River, Joli Fou, and Viking Formations of central and northern Alberta (Norris 1967; Singh 1971) which are marine units containing elements of the late Middle Albian *Gastroplites* fauna and the *Haplophragmoides gigas* microfauna which perhaps ranges into the the earliest Late Albian. First appearances of dicotyledonous pollen in the Moose River Basin during this interval are in accord with this age.

It is noteworthy that *Lophotriletes babsae* (restricted to the *Tigrisporites-T. humilis* zone) first appears at the base of the marine Middle Albian

of England (Kemp 1968, 1970; Laing 1976). Its first appearance characterizes the base of the Middle Albian palynologic Subzone IIA of the Atlantic Coastal Plain (Doyle and Robbins 1977), and it occurs rarely in the late Middle Albian basal Cadotte Member of the Peace River Formation (Singh 1971). Furthermore, the occurrences of *Cicatricosisporites patapscoensis* and *Cicatricosisporites subrotundus* define the base of Subzone IIB of the Atlantic Coastal Plain (Brenner 1963) which is now believed to be Middle and early Late Albian in age (Doyle and Robbins 1977). Thus the balance of evidence indicates a late Middle Albian age for the *Tigrisporites-Trilobosporites humilis* zone.

Impardecispora purverulenta-Cicatricosisporites annulatus Interval Zone

This zone occurs between 39 m and 41 m in drillhole 75-05 (see Figure 2.8) and may also be represented by impoverished assemblages in drillhole 75-06 between 54 m and 124 m.

The *I. purverulenta-C. annulatus* zone is marked by the local range tops of the following species:
Appendicisporites problematicus (Burger) Singh* (Plate 4, fig.21, 22)
Biretisporites potoniei Delcourt and Sprumont (Plate 1, fig. 14)
Camarozonosporites insignis Norris (Plate 6, fig. 9-11)
441 *Cicatricosisporites-1* (Plate 3, fig. 19-22)
Clavatipollenites hughesii Couper (Plate 8, fig. 8-15)
Concavissimisporites sp. cf. *C. punctatus* (Delcourt and Sprumont) Brenner (Plate 1, fig. 10)
Coptospora sp. cf. *C. striata Dettmann* (Plate 7, fig. 14-23)
Crybelosporites brenneri Playford (Plate 6, fig. 18-20)
Cupuliferoidaepollenites minutus (Brenner) Singh (Plate 11, fig. 2, 3)
Densoisporites sp. cf. *D. perinatus* Couper (Plate 6, fig. 13, 17)
424 *Distaltriangulisporites-1* (Plate 2, fig. 14-17)
Distaltriangulisporites perplexus (Singh) Singh* (Plate 2, fig.23)
Eucommiidites minor Groot and Penny (Plate 8, fig. 16-19)
430 *Exesipollenites-1* (Plate 8, fig. 2,3)
442 *Fungus-1* (Plate 12, fig. 1-4)
Klukisporites sp. cf. *K. areolatus* Singh (Plate 3, fig. 1-3)
453 *Neoraistrickia-1* (Plate 2, fig. 3, 4)
426 *Parvisaccites-1*
444 *Phimopollis-1* (Plate 11, fig. 6-8)
Platysaccus megasaccus Brenner (Plate 10, fig. 7, 8)
450 *Pristinuspollenites-2* (Plate 8, fig. 23-32)
Rugubivesiculites reductus Pierce* (Plate 10, fig. 9-12)
434 *Trilobosporites-1* (Plate 5, fig. 20)

Those species marked * may occur higher (see next section).In addition the following species appear to be restricted to this zone:
Appendicisporites sp. cf. *A. potomacensis* Brenner (Plate 4, fig. 8)
Aratrisporites ocellatus Hedlund and Norris (Plate 8, fig. 21)
425 *Araucariacites-1* (Plate 8, fig. 1)
432 *Callialasporites-2* (Plate 8, fig. 22)
Cicatricosisporites annulatus Archangelsky and Gamerro (Plate 3, fig. 12)

Cicatricosisporites sp. cf. *Anemia exilioides* (Maljavkina) Bolchovitina (Plate 4, fig. 5-7)
Cicatricosisporites sp. cf. *C. hughesi* Dettmann (Plate 3, fig. 15)
447 *Cupuliferoidaepollenites-2* (Plate 11, fig. 12-14)
Cyathidites punctatus (Delcourt and Sprumont) Delcourt, Dettmann, and Hughes
Densoisporites circumundulatus (Brenner) Playford (Plate 6, fig. 16)
Dictyophyllidites equiexinus (Couper) Dettmann (Plate 1, fig. 4)
438 *Inaperturopollenites-3* (Plate 7, fig. 28)
Impardecispora purverulenta (Verbitskaya) Venkatachala *et al.* (Plate 5, fig. 11-14)
Impardecispora sp. cf. *I. trioreticulosa* (Cookson and Dettmann) Venkatachala *et al.* (Plate 5, fig. 15-18)
Lycopodiacidites sp. cf. *L. ambifoveolatus* Brenner (Plate 2, fig. 33, 39)
Lycopodiacidites sp. cf. *L. asperatus* Dettmann
Lycopodiacidites sp. cf. *L. expansus* Singh
Lycopodiumsporites marginatus Singh (Plate 3, fig. 6, 7)
455 *Marattisporites-1* (Plate 7, fig. 24)
Monosulcites chaloneri Brenner (plate 8, fig. 20)
423 *Perotriletes-2* (Plate 6, fig. 15)
Psilatriletes sp. cf. *P. radiatus* Brenner (Plate 1, fig. 3)
446 *Rouseia-1* (Plate 11, fig. 9-11)
Schizosporis spriggi Cookson and Dettmann (Plate 12, fig. 6,7)
449 *Taurocusporites-1* (plate 3, fig. 10)
Todisporites major Couper
Trilobosporites crassus Brenner (Plate 5, fig. 10)
Trilobosporites marylandensis Brenner
429 *Tripartina-1* (Plate 2, fig. 13)
454 *Tuberosisporites-1* (Plate 1, fig. 11)

The occurrences of *Aratrisporites ocellatus* and *Monosulcites chaloneri* in this zone are noteworthy because they occur together in the Fredericksburgian Antlers-"Walnut" sequence of southern Oklahoma (Hedlund and Norris 1968), dated by ammonites in adjacent sections of north Texas as late Middle Albian (see further discussions of age in Srivastava 1975). Angiosperm pollen diversity in the Moose River Basin, however, is considerably less than in the Gulf Coastal and Atlantic Coastal Plains, consistent with its higher paleolatitudinal position. Several pteridophyte spore species also indicate a correlation with palynologic Subzone IIB of the Atlantic Coastal Plain, dated by Doyle and Robbins (1977) as late Middle and early Late Albian and correlated with the basal Colorado Group and upper Peace River Formation of Alberta (Norris 1967; Singh 1971) which are of similar ages. Thus a late Middle Albian age accords with the bulk of the evidence, although the possibility of an extension into the early Late Albian cannot be rejected.

Upper Albian

A distinctive palynoflora comprising 25 species was obtained by Norris *et al.* (1976) from outcrop on the east bank of the Mattagami River in Kipling Township, 0.8 km north of the foot of Long Rapids which is 9.7 km north of Smoky Falls.

Apart from long-ranging species, the following are noteworthy:
Appendicisporites problematicus (Burger) Singh (Plate 4, fig. 21, 22)
Cicatricosisporites augustus Singh
Cicatricosisporites australis (Cookson) Potonié (Plate 3, fig. 17, 18)
Cicatricosisporites hughesi Dettmann (Plate 3, fig. 16)
Cicatricosisporites sp. cf. *C. hallei* Delcourt and Sprumont (Plate 4, fig. 3)
Costatoperforosporites foveolatus Deak (Plate 3, fig. 32-34)
Cupuliferoidaepollenites parvulus (Groot and Penny) Dettmann
Distaltriangulisporites perplexus (Singh) Singh (Plate 2, fig. 23)
Ornamentifera baculata Singh
Pristinuspollenites inchoatus (Pierce) B.D. Tschudy
Retitricolpites vulgaris Pierce
Rugubivesiculites reductus Pierce (Plate 10, fig. 9-12)
Tricolpites sagax Norris
Trilobosporites minor Pocock

Similarities with the *I. purverulenta-C.annulatus* Zone (late Middle and early Late Albian) are evident. In addition, however, *Pristinuspollenites inchoatus*, *Rugubivesiculites reductus*, *Cupuliferoidaepollenites parvulus*, *Retitricolpites vulgaris* and *Tricolpites sagax* characterize this sample. These species occur together in the Upper Albian of Alberta (Norris 1967; Singh 1971).

Norris, Jarzen, and Awai-Thorne (1975) have also reported the occurrence of these species together with marine dinoflagellate assemblages in the upper part of their Early Tricolpate Suite and higher subsurface Cretaceous horizons in southern Alberta, suggesting an age of Late Albian for the base of this interval. Furthermore, the latter three angiosperm species occur together only near the Subzone IIC-Zone III boundary of the Atlantic Coastal Plain, and placed by Doyle and Robbins (1977) at the Upper Albian/Cenomanian boundary. Thus a Late Albian age is considered probable for this sample, although further work on the outcrop is required to confirm this.

CORRELATIONS

Correlations between the Moose River Basin, the Atlantic Coastal Plain and Western Canada are shown in Figure 4.1. These correlations are based on spore-pollen distributions as indicated in the previous discussion.

The Mattagami Formation was deposited principally during the Middle and Late Albian and represents part of a major phase of cratonic sedimentation recognizable also in Alberta, Saskatchewan, and Manitoba. These Albian sediments are entirely non-marine in the Moose River Basin but farther west they interdigitate with marine sediments (Singh 1971), e.g. Loon River Formation,

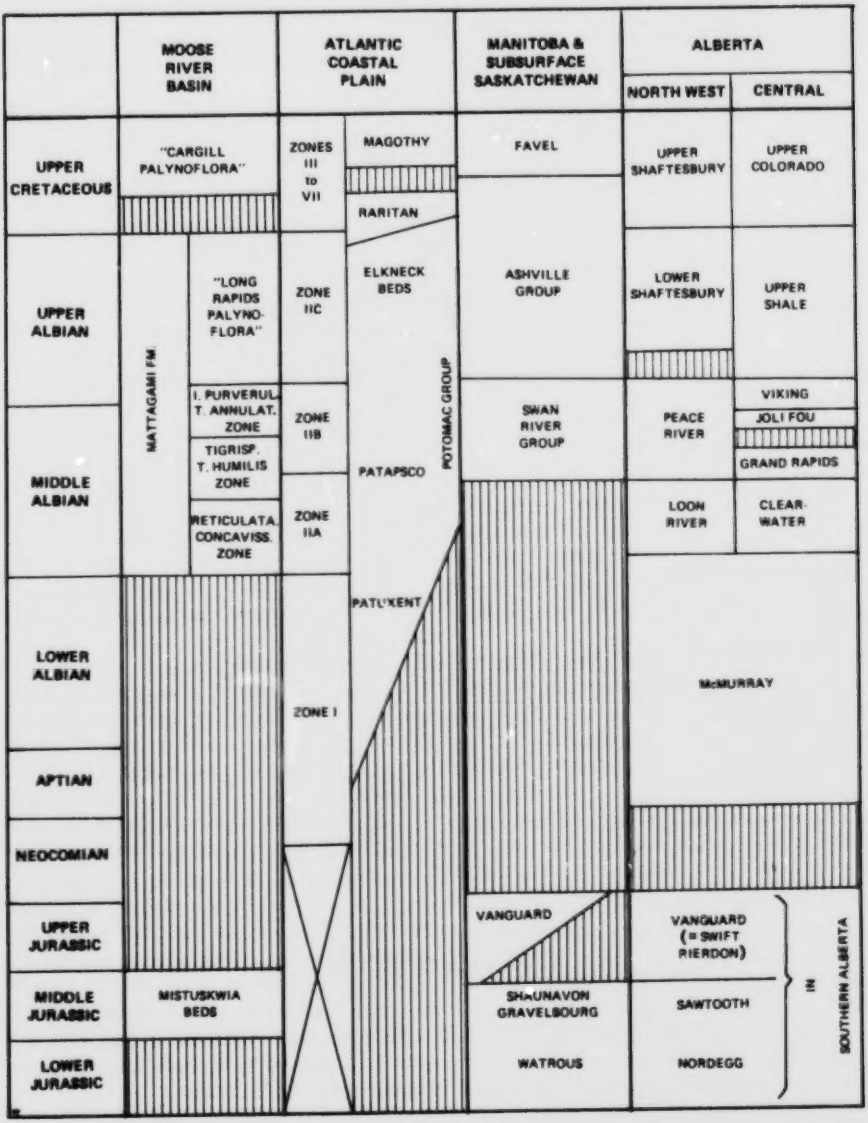

Figure 4.1–Correlation of Mesozoic sediments of the Moose River Basin with other areas.

Clearwater Formation, and Colorado Group of Alberta; Ashville Group of Manitoba. Correlative strata in the eastern Canadian offshore region are thick marine and deltaic sandstones and shales (Logan Canyon Formation) deposited on a subsiding shelf (Gradstein *et al.* 1975; Jansa and Wade 1975).

On the Atlantic Coastal Plain of Virginia, Maryland, Delaware, and New Jersey, the fluvial-deltaic Potomac Group (Doyle and Robbins 1977) is partially correlative with the Mattagami Formation. Palynofloras from the Magothy Formation (Upper Santonian-Lower Campanian) are characterized by various advanced Normapolles genera, some of which have been found in a carbonaceous horizon in a drillhole in Cargill Township, Ontario. This assemblage is provisionally called the "Cargill Palynoflora" and will be the subject of a subsequent study.

The extensive hiatus between the Albian Mattagami Formation and the Middle Jurassic Mistuskwia Beds is noteworthy. The Mistuskwia Beds occur in two drillholes in the central part of the Moose River Basin (Telford *et al.* 1975; Telford, this report) and have been dated palynologically as Middle Jurassic and correlated tentatively with the Gravelbourg and Shaunavon Formations of the Williston Basin (Norris 1977). The precise stratigraphic and structural relationships between the Mattagami Formation and the Mistuskwia Beds are not yet established. A similar hiatus is present, however, in Manitoba and Saskatchewan between the Albian Swan River Group and the underlying Jurassic (Playford 1971).

ACKNOWLEDGMENTS

This work was made possible with a grant from the Ontario Geoscience Research Fund (Grant No. 19). I thank Peter Telford, Harish Verma, and Max Vos for information on stratigraphy of the Moose River Basin and for facilitating the collection of samples through the Ontario Geological Survey. Anne Naldrett and Patricia Dobell provided valuable photographic and technical assistance for this project.

Plate 1. All figures 500X
Fig. 1. *Stereisporites antiquasporites* (Wilson and Webster) Dettmann
Fig. 2. *Stereisporites antiquasporites* (Wilson and Webster) Dettmann
Fig. 3. *Psilatriletes* sp. cf. *P. radiatus* Brenner
Fig. 4. *Dictyophyllidites equiexinus* (Couper) Dettmann
Fig. 5. *Deltoidospora juncta* (Kara-Murza) Singh
Fig. 6. 497 *Tripartina - 2*
Fig. 7. *Cyathidites minor* Couper
Fig. 8. *Todisporites major* Couper
Fig. 9. *Concavissimisporites punctatus* (Delcourt and Sprumont) Brenner
Fig. 10. *Concavissimisporites* sp. cf. *C. punctatus* (Delcourt and Sprumont) Brenner
Fig. 11. 454 *Tuberosisporites-1*
Fig. 12. 477 *Baculatisporites-1*
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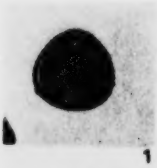
Fig. 14. *Biretisporites potoniei* Delcourt and Sprumont
Fig. 15. *Biretisporites potoniei* Delcourt and Sprumont
Fig. 16. *Biretisporites potoniei* Delcourt and Sprumont
Fig. 17. *Osmundacidites wellmanii* Couper
Fig. 18. *Converrucosisporites variverrucatus* (Couper) Norris
Fig. 19. *Baculatisporites comaumensis* (Cookson) Potonié
Fig. 20. 483 *Baculatisporites-2*
Fig. 21. 483 *Baculatisporites-2*
Fig. 22. 483 *Baculatisporites-2*
Fig. 23. *Acanthotriletes* sp. cf. *A. varispinsous* Pocock
Fig. 24. *Converrucosisporites* sp. cf. *C. platyverrucosus* Brenner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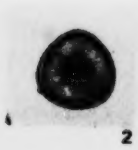
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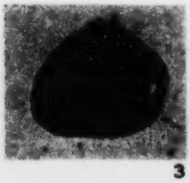
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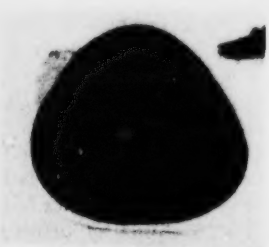
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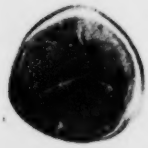
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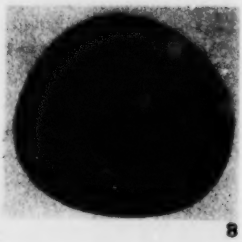
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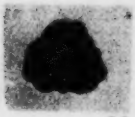
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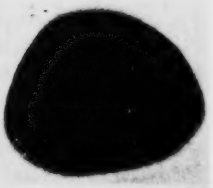
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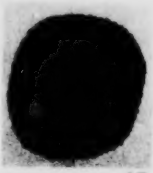
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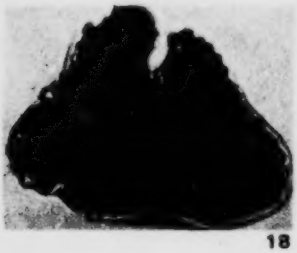
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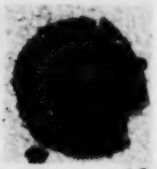
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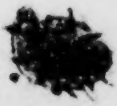
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Plate 2. All figures 500X
Fig. 1. 494 *Concavissimisporites-1*
Fig. 2. 494 *Concavissimisporites-1*
Fig. 3. 453 *Neoraistrickia-1*
Fig. 4. 453 *Neoraistrickia-1*
Fig. 5. *Lophotriletes babsae* (Brenner) Singh
Fig. 6. *Lophotriletes babsae* (Brenner) Singh
Fig. 7. *Lophotriletes babsae* (Brenner) Singh
Fig. 8. *Reticulisporites elongatus* (Singh)
Fig. 9. *Foveotriletes subtriangularis* Brenner
Fig.10. *Sestrosporites pseudoalveolatus* (Couper) Dettmann
Fig.11. *Distaltriangulisporites irregularis* Singh
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Fig.13. 429 *Tripartina-1*
Fig.14. 424 *Distaltriangulisporites-1*
Fig.15. 424 *Distaltriangulisporites-1*
Fig.16. 424 *Distaltriangulisporites-1*
Fig.17. 424 *Distaltriangulisporites-1*
Fig.18. *Microreticulatisporites uniformis* Singh
Fig.19. *Microreticulatisporites uniformis* Singh
Fig.20. *Microreticulatisporites uniformis* Singh
Fig.21. *Tigrisporites* sp. B. Singh
Fig.22. *Tigrisporites* sp. B. Singh
Fig.23. *Distaltriangulisporites perplexus* (Singh) Singh
Fig. 24. *Tigrisporites scurrandus* Norris
Fig.25. *Tigrisporites scurrandus* Norris
Fig.26 *Tigrisporites scurrandus* Norris
Fig.27. *Tigrisporites scurrandus* Norris
Fig.28. *Tigrisporites reticulatus* Singh
Fig.29. *Tigrisporites reticulatus* Singh
Fig.30. *Tigrisporites reticulatus* Singh
Fig.31. *Tigrisporites reticulatus* Singh
Fig.32. *Klukporites foveolatus* Pocock
Fig.33. *Lycopodiacidites sp. cf. L. ambifoveolatus* Brenner
Fig.34. *Lycopodiacidites sp. cf. L. ambifoveolatus* Brenner

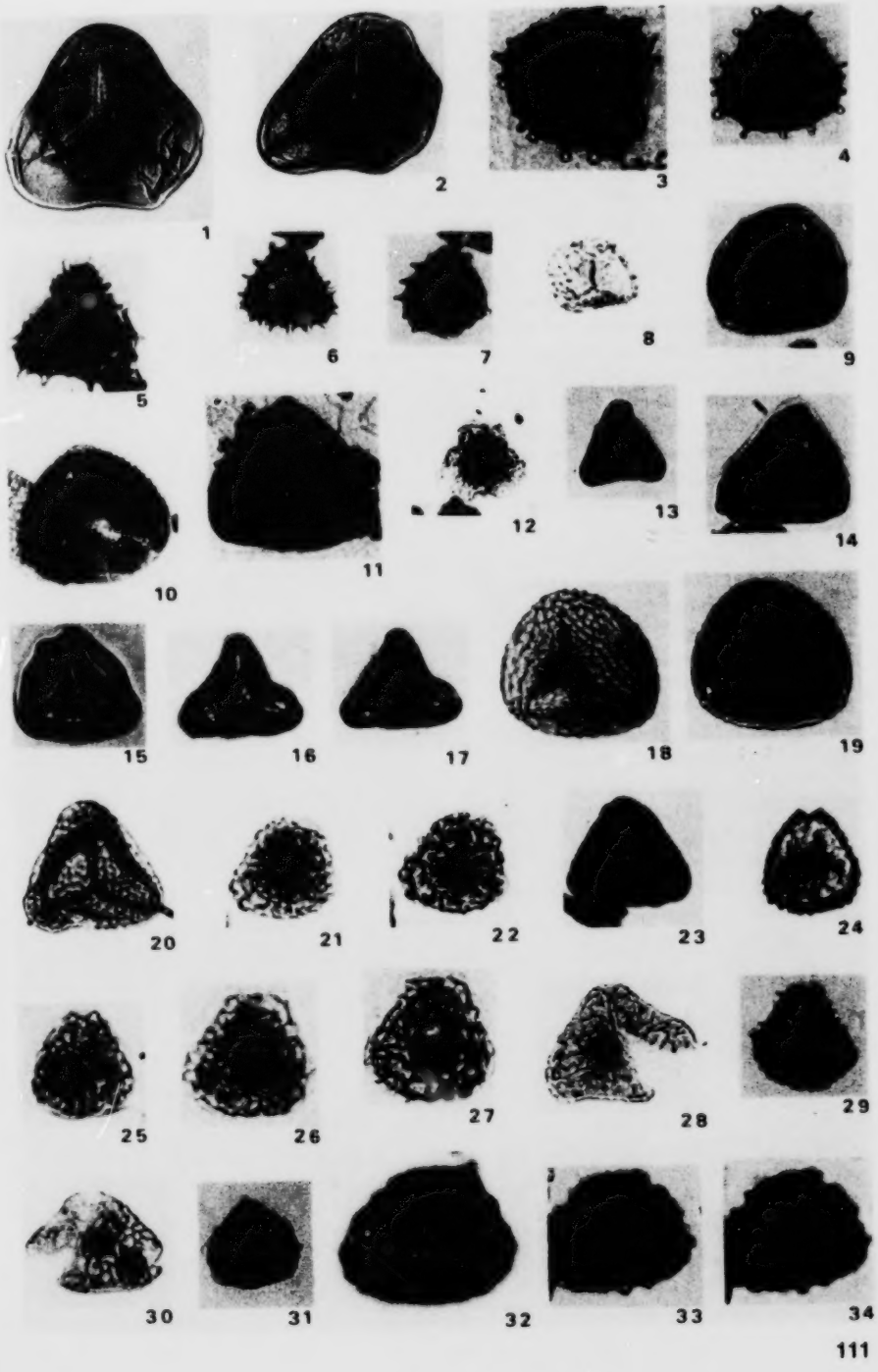
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Plate 3 All figures 500X
Fig. 1. *Klukisporites* sp. cf. *K. areolatus* Singh
Fig. 2. *Klukisporites sp. cf. K. areolatus Singh*
Fig. 3. *Klukisporites sp. cf. K. areolatus Singh*
Fig. 4. *Klukisporites* sp. cf. *K. pseudoreticulatus* Couper
Fig. 5. *Taurocusporites* sp. cf. *T. segmentatus* Stover
Fig. 6. *Lycopodiumsporites marginatus* Singh
Fig. 7. *Lycopodiumsporites marginatus* Singh
Fig. 8. *Lycopodiumsporites* sp. cf. *L. expansus* Singh
Fig. 9 *Lycopodiumsporites* sp. cf. *L. expansus* Singh
Fig.10. 449 *Taurocusporites-1*
Fig.11. *Taurocusporites segmentatus* Stover
Fig.12. *Cicatricosisporites annulatus* Archangelsky and Gamerro
Fig.13. *Cicatricosisporites potomacensis* Brenner
Fig.14. *Cicatricosisporites potomacensis* Brenner
Fig.15. *Cicatricosisporites* sp. cf. *C. hughesi* Dettmann
Fig.16. *Cicatricosisporites hughesi* Dettman
Fig.17. *Cicatricosisporites australis* (Cookson) Potonié
Fig.18. *Cicatricosisporites australis* (Cookson) Potonié
Fig.19. 441 *Cicatricosisporites-1*
Fig.20. 441 *Cicatricosisporites-1*
Fig.21. 441 *Cicatricosisporites-1*
Fig.22. 441 *Cicatricosisporites-1*
Fig.23. *Cicatricosisporites orbiculatus* Singh
Fig.24. *Cicatricosisporites* sp. cf. *C. hallei* Delcourt and Sprumont
Fig.25. *Cicatricosisporites* sp. cf. *C. hallei* Delcourt and Sprumont
Fig.26. 503 *Cicatricosisporites-2*
Fig.27. 503 *Cicatricosisporites-2*
Fig.28. 503 *Cicatricosisporites-2*
Fig.29. 503 *Cicatricosisporites-2*
Fig.30. *Cicatricosisporites* sp. cf. *C. ludbrooki* Dettmann
Fig.31. *Cicatricosisporites* sp. cf. *C. ludbrooki* Dettmann
Fig.32. *Costatoperforosporites foveolatus* Deak
Fig.33. *Costatoperforosporites foveolatus* Deak
Fig.34. *Costatoperforosporites foveolatus* Deak

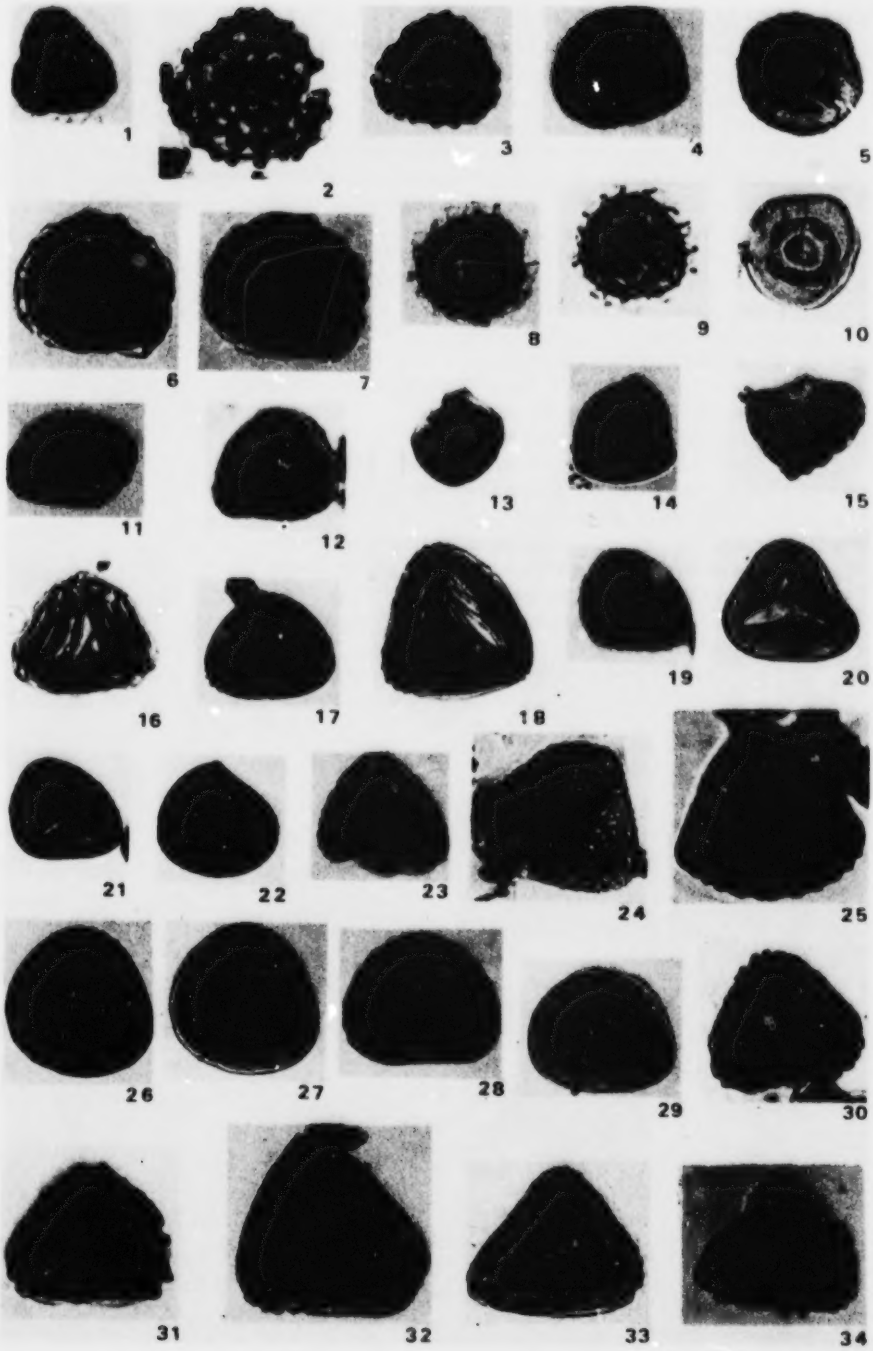
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Plate 4 All figures 500X
Fig. 1. *Cicatricosisporites hallei* Delcourt and Sprumont
Fig. 2. *Cicatricosisporites hallei* Delcourt and Sprumont
Fig. 3. *Cicatricosisporites* sp. cf. *C. hallei* Delcourt and Sprumont
Fig. 4. *Costatoperforosporites fistulosus* Deak
Fig. 5. *Cicatricosisporites* sp. cf. *Anemia exilioides* (Maljavkina) Bolchovitina
Fig. 6. *Cicatricosisporites* sp. cf. *Anemia exilioides* (Maljavkina) Bolchovitina
Fig. 7. *Cicatricosisporites* sp. cf. *Anemia exilioides* (Maljavkina) Bolchovitina
Fig. 8. *Appendicisporites* sp. cf. *A. potomacensis* Brenner
Fig. 9. *Appendicisporites* sp. cf. *A. macalesteri* Pocock
Fig.10. *Appendicisporites* sp. cf. *A. macalesteri* Pocock
Fig.11. *Cicatricosisporites Subrotundus* Brenner
Fig.12. *Appendicisporites spinosus* Pocock
Fig.13. *Appendicisporites spinosus* Pocock
Fig.14. *Appendicisporites crimensis* (Bolchovitina) Pocock
Fig.15. *Appendicisporites bilateralis* Singh
Fig.16. *Appendicisporites bilateralis* Singh
Fig.18. *Appendicisporites bilateralis* Singh
Fig.19. *Appendicisporites bilateralis* Singh
Fig.20. *Appendicisporites erdtmanii* Pocock
Fig.21. *Appendicisporites problematicus* (Burger) Singh
Fig.22. *Appendicisporites problematicus* (Burger) Singh
Fig.23. *Appendicisporites unicus* (Markova) Singh
Fig.24. *Appendicisporites unicus* (Markova) Singh
Fig.25. 487 *Foraminisporis-1*
Fig.26. *Trilobosporites hannonicus* Delcourt and Sprumont

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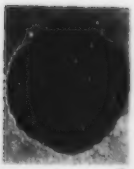
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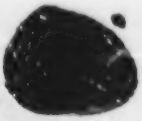
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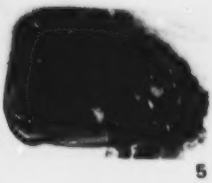
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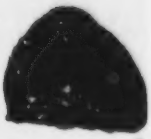
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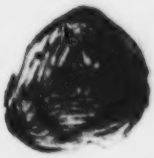
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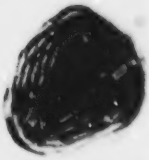
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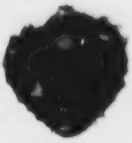
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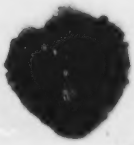
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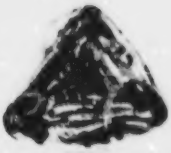
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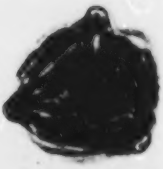
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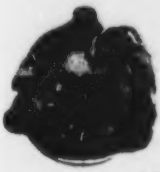
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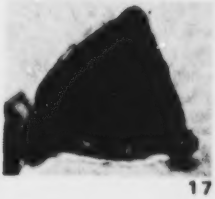
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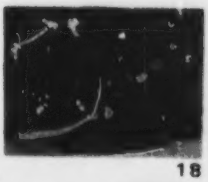
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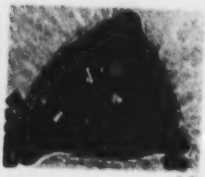
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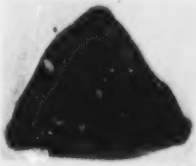
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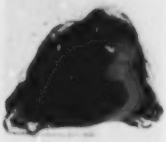
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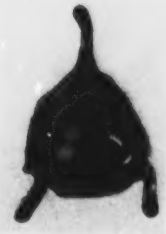
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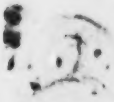
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Plate 5 All figures 500X
Fig. 1. 486 *Trilobosporites-2*
Fig. 2. 486 *Trilobosporites-2*
Fig. 3. *Trilobosporites humilis* Delcourt and Sprumont
Fig. 4. *Trilobosporites humilis* Delcourt and Sprumont
Fig. 5. *Trilobosporites humilis* Delcourt and Sprumont
Fig. 6. *Trilobosporites humilis* Delcourt and Sprumont
Fig. 7. *Trilobosporites humilis* Delcourt and Sprumont
Fig. 8. *Trilobosporites humilis* Delcourt and Sprumont
Fig. 9. *Impardecispora* sp. cf. *I. marylandensis* (Brenner) Srivastava
Fig.10. *Trilobosporites crassus* Brenner
Fig.11. *Impardecispora purverulenta* (Verbitskaya) Venkatachala *et al.*
Fig.12. *Impardecispora purverulenta* (Verbitskaya) Venkatachala *et al.*
Fig.13. *Impardecispora purverulenta* (Verbitskaya) Venkatachala *et al.*
Fig.14. *Impardecispora purverulenta* (Verbitskaya) Venkatachala *et al.*
Fig.15. *Impardecispora* sp. cf. *I. trioreticulosa* (Cookson and Dettmann) Venkatachala *et al.*
Fig.16. *Impardecispora* sp. cf. *I. trioreticulosa* (Cookson and Dettmann) Venkatachala *et al.*
Fig.17. *Impardecispora* sp. cf. *trioreticulosa* (Cookson and Dettmann) Venkatachala *et al.*
Fig.18. *Impardecispora* sp. cf. *I. trioreticulosa* (Cookson and Dettmann) Venkatachala *et al.*
Fig.19. *Impardecispora trioreticulosa* (Cookson and Dettmann) Venkatachala *et al.*
Fig.20. 434 *Trilobosporites*-I
Fig.21. *Impardecispora tribotrys* (Dettmann) Venkatachala *et al.*
Fig.22. *Impardecispora tribotrys* (Dettmann) Venkatachala *et al.*
Fig.23. 482 *Uvaesporites-1*
Fig.24. 482 *Uvaesporites-1*
Fig.25. *Foraminisporis asymmetricus* (Cookson and Dettmann) Dettmann
Fig.26. *Foraminisporis asymmetricus* (Cookson and Dettmann) Dettmann

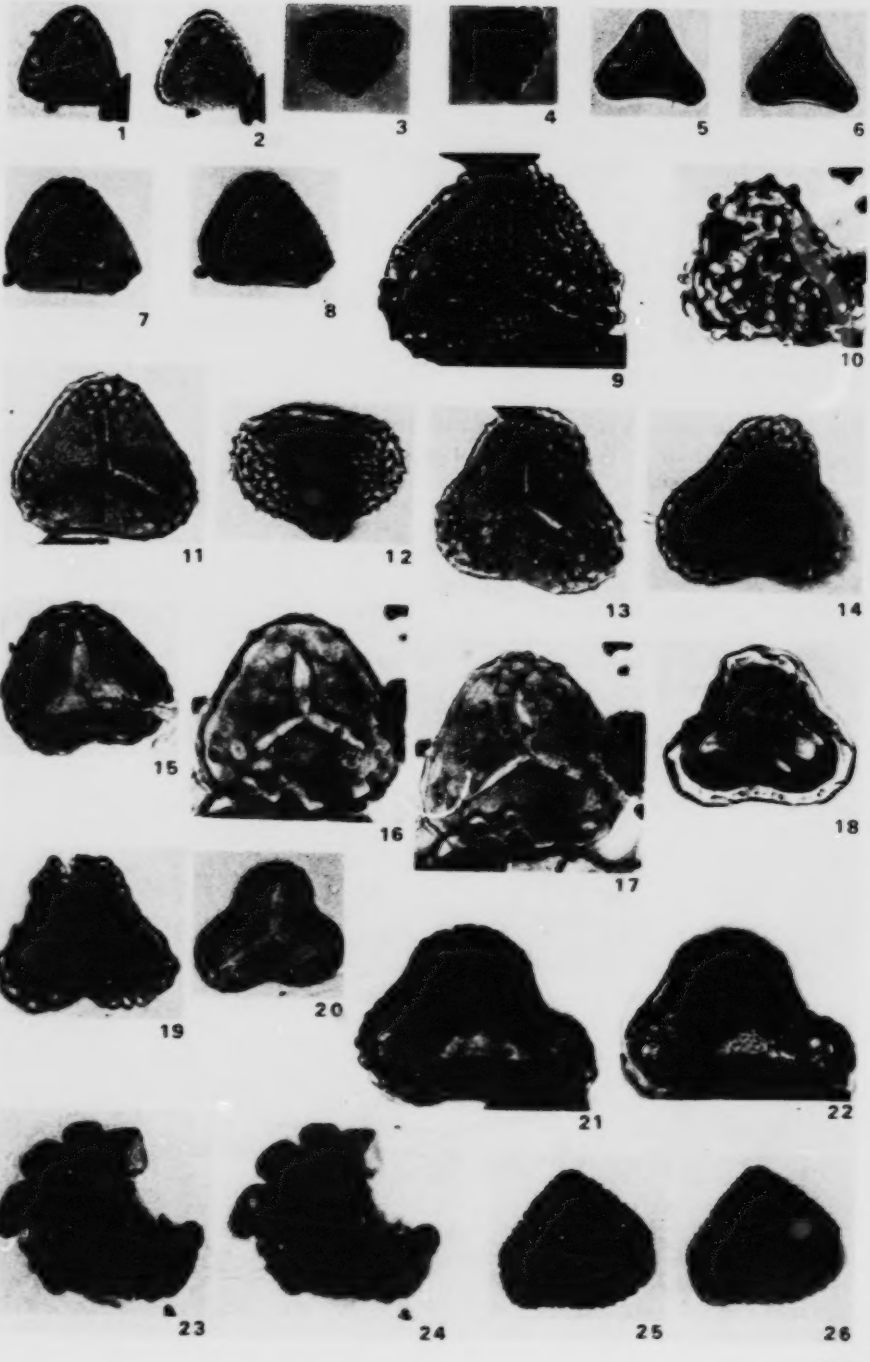
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Plate 6 All figures 500X
Fig. 1. 496 *Gleicheniidites-1*
Fig. 2. 496 *Gleicheniidites-1*
Fig. 3. 496 *Gleicheniidites-1*
Fig. 4. 496 *Gleicheniidites-1*
Fig. 5. 496 *Gleicheniidites-1*
Fig. 6. 496 *Gleicheniidites-1*
Fig. 7. 496 *Gleicheniidites-1*
Fig. 8. *Gleicheniidites senonicus* Ross
Fig. 9. *Camarozonosporites insignis* Norris
Fig. 10. *Camarozonosporites insignis* Norris
Fig. 11. *Camarozonosporites insignis* Norris
Fig. 12. *Ornamentifera echina* a (Bolchovitina) Bolchovitina
Fig. 13. *Densoisporites* sp. cf. *D. perinatus* Couper
Fig. 14. 476 *Perotrilites-1*
Fig. 15. 423 *Perotrilites-2*
Fig. 16. *Densoisporites circumundulatus* (Brenner) Playford
Fig. 17. *Densoisporites* sp. cf. *D. perinatus* Couper
Fig.18. *Crybelosporites brenneri* Playford
Fig.19. *Crybelosporites brenneri* Playford
Fig.20. *Crybelosporites brenneri* Playford
Fig.21. *Triporoletes reticulatus* (Pocock) Playford
Fig.22. *Triporoletes reticulatus* (Pocock) Playford
Fig.23. *Triporoletes reticulatus* (Pocock) Playford
Fig.24. *Triporoletes reticulatus* (Pocock) Playford
Fig.25. *Triporoletes reticulatus* (Pocock) Playford
Fig.26. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann
Fig.27. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann

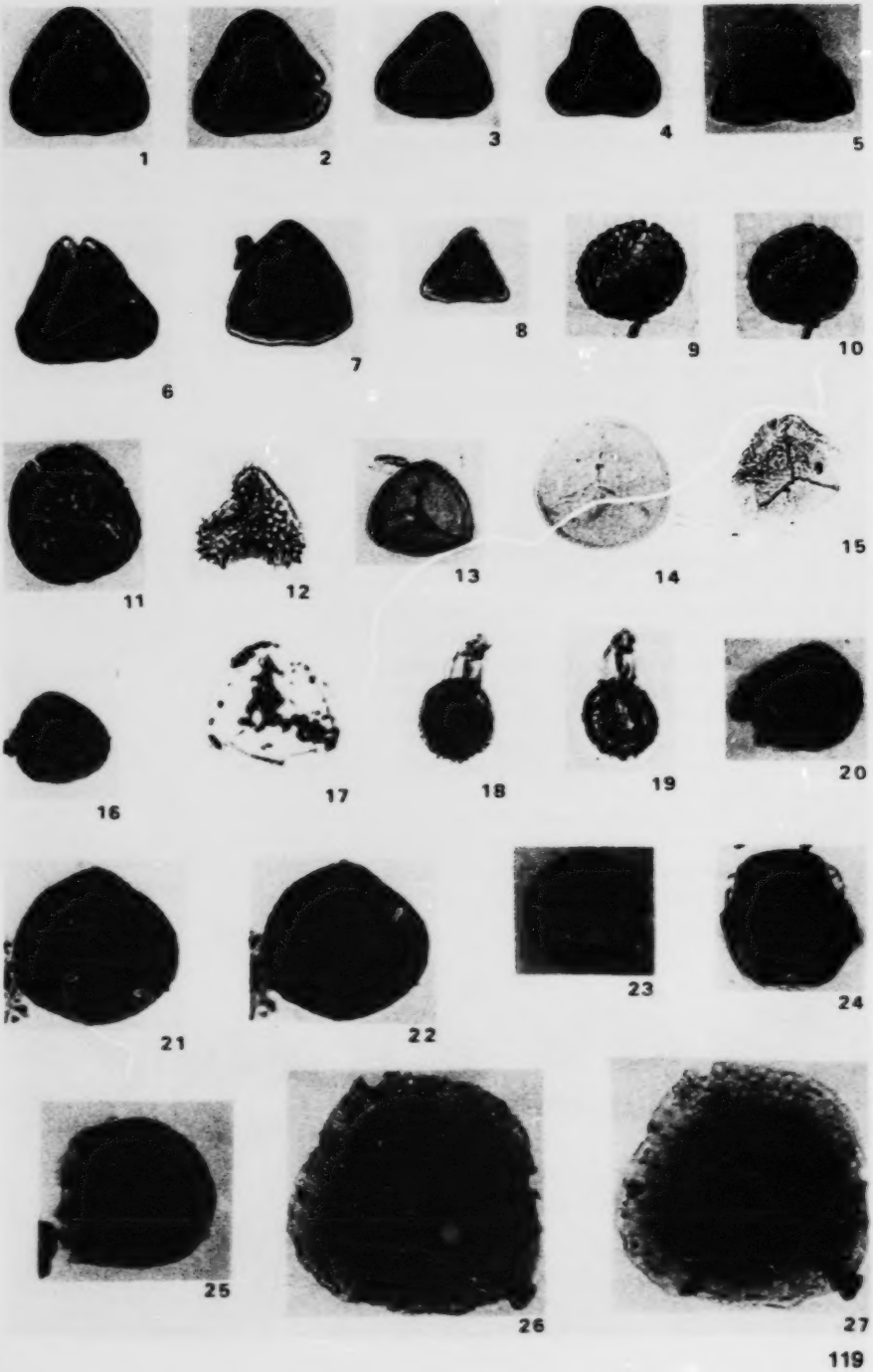
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Plate 7 All figures 500X
Fig. 1. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann
Fig. 2. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann
Fig. 3. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann
Fig. 4. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann
Fig. 5. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann
Fig. 6. *Aequitriradites spinulosus* (Cookson and Dettmann) Cookson and Dettmann
Fig. 7. *Triporoletes radiatus* (Dettmann) Playford
Fig. 8. 489 *Coptospora-1*
Fig. 9. 489 *Coptospora-1*
Fig. 10. 489 *Coptospora-1*
Fig. 11. 489 *Coptospora-1*
Fig. 12. 469 *Cooksonites -1*
Fig. 13. 469 *Cooksonites-1*
Fig. 14. *Coptospora* sp. cf. *C. striata* Dettmann
Fig. 15. 469 *Cooksonites-1*
Fig. 16. 469 *Cooksonites-1*
Fig. 17. *Coptospora* sp. cf. *C. striata* Dettmann
Fig. 18. *Coptospora* sp. cf. *C. striata* Dettmann
Fig. 19. *Coptospora* sp. cf. *C. striata* Dettmann
Fig. 20. *Coptospora* sp. cf. *C. striata* Dettmann
Fig. 21. *Coptospora* sp. cf. *C. striata* Dettmann
Fig. 22. *Coptospora* sp. cf. *C. striata* Dettmann
Fig. 23. *Coptospora* sp. cf. *C. striata* Dettmann
Fig. 24. 455 *Marattisporites-1*
Fig. 25. *Laevigatosporites ovatus* Wilson and Webster
Fig. 26. *Taxodiaceaepollenites hiatus* (Potonié) Kremp
Fig. 27. *Taxodiaceaepollenites hiatus* (Potonié) Kremp
Fig. 28. 438 *Inaperturopollenites-3*

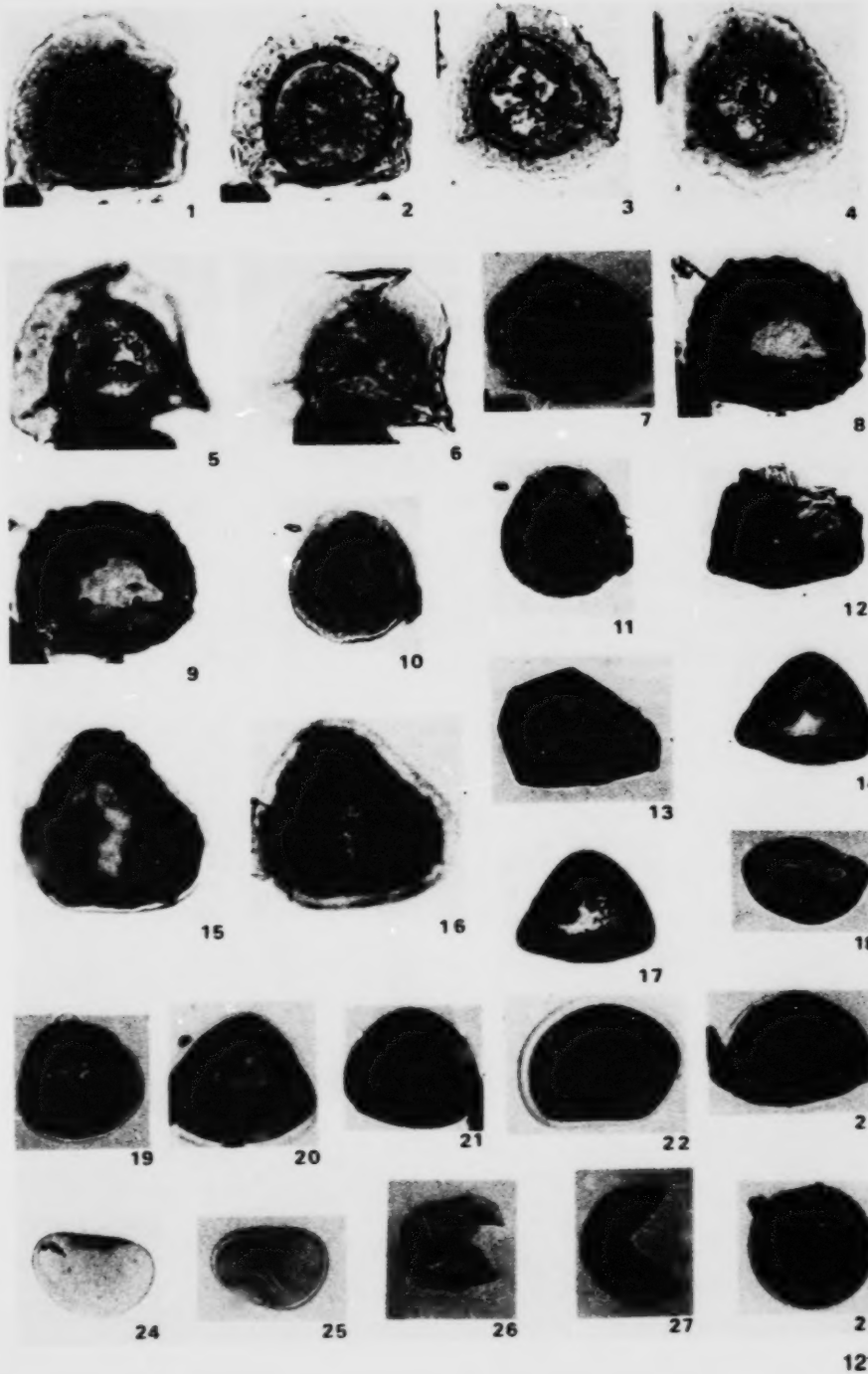
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Plate 8 All figures 500X
Fig. 1. 425 *Araucariacites-1*
Fig. 2. 430 *Exesipollenites-1*
Fig. 3. 430 *Exesipollenites-1*
Fig. 4. *Perinopollenites elatoides* Couper
Fig. 5. *Perinopollenites elatoides* Couper
Fig. 6. *Classopollis torosus* (Reissinger) Balme
Fig. 7. *Circulina parva* Brenner
Fig. 8. *Clavatipollenites hughesi* Couper
Fig. 9. *Clavatipollenites hughesi* Couper
Fig. 10. *Clavatipollenites hughesi* Couper
Fig. 11. *Clavatipollenites hughesi* Couper
Fig. 12. *Clavatipollenites hughesi* Couper
Fig. 13. *Clavatipollenites hughesi* Couper
Fig. 14. *Clavatipollenites hughesi* Couper
Fig. 15. *Clavatipollenites hughesi* Couper
Fig. 16. *Eucommiidites minor* Groot and Penny
Fig. 17. *Eucommiidites minor* Groot and Penny
Fig. 18. *Eucommiidites minor* Groot and Penny
Fig. 19. *Eucommiidites minor* Groot and Penny
Fig. 20. *Monosulcites chaloneri* Brenner
Fig. 21. *Aratrisporites ocellatus* Hedlund and Norris
Fig. 22. 432 *Callialasporites-2*
Fig. 23. 450 *Pristinuspollenites-2*
Fig. 24. 450 *Pristinuspollenites-2*
Fig. 25. 450 *Pristinuspollenites-2*
Fig. 26. 450 *Pristinuspollenites-2*
Fig. 27. 450 *Pristinuspollenites-2*
Fig. 28. 450 *Pristinuspollenites-2*
Fig. 29. 450 *Pristinuspollenites-2*
Fig. 30. 450 *Pristinuspollenites-2*
Fig. 31. 450 *Pristinuspollenites-2*
Fig. 32. 450 *Pristinuspollenites-2*
Fig. 33. *Cedripites canadensis* Pocock
Fig. 34. *Cedripites canadensis* Pocock
Fig. 35. *Vitreisporites pallidus* (Reissinger) Potonié

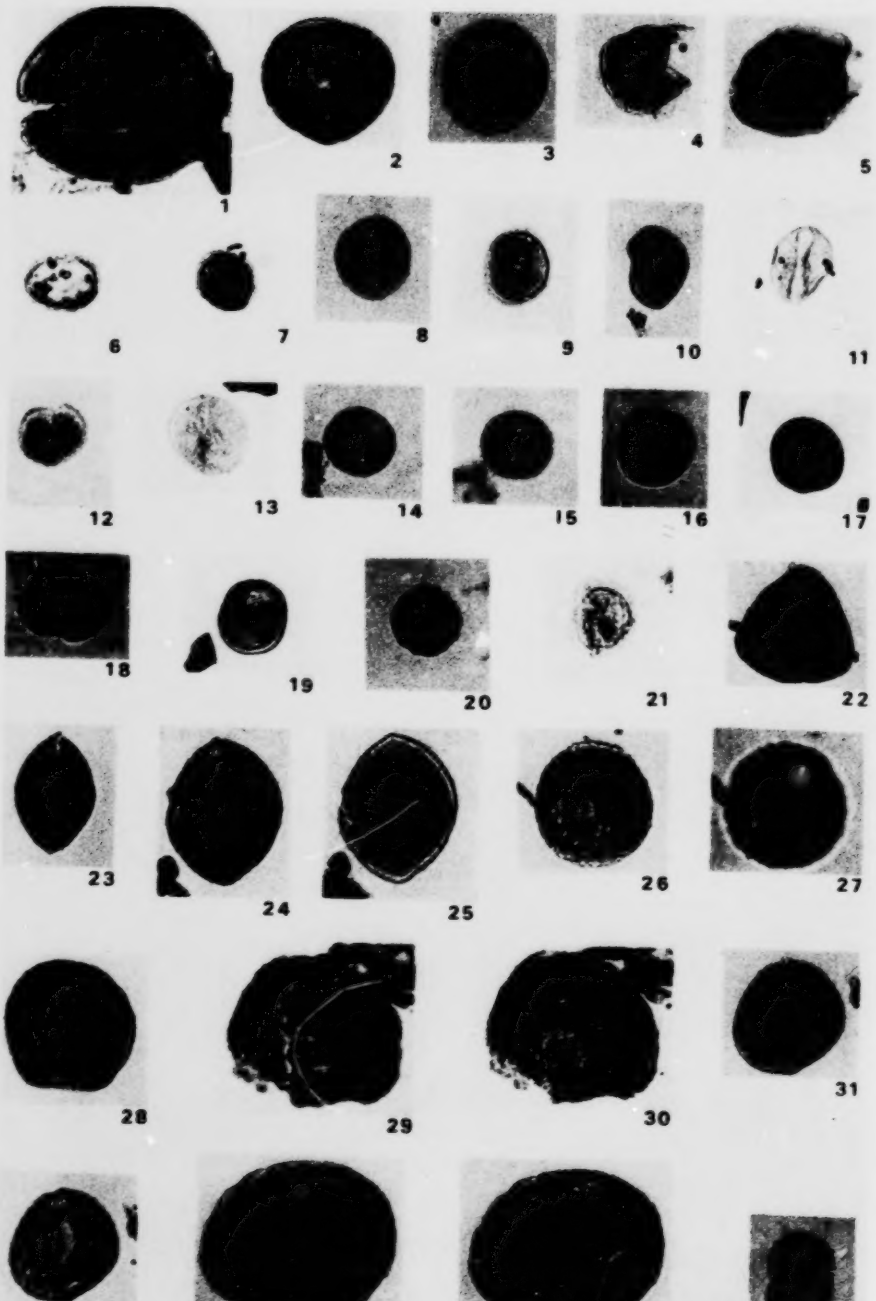
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Plate 9 All figures 500X
Fig. 1. 479 *Parvisaccites-2*
Fig. 2. 479 *Parvisaccites-2*
Fig. 3. *Parvisaccites radiatus* Couper
Fig. 4. *Parvisaccites radiatus* Couper
Fig. 5. *Parvisaccites radiatus* Couper
Fig. 6. 474 *Pteruchipollenites-1*
Fig. 7. 474 *Pteruchipollenites-1*
Fig. 8. 471 *Pristinuspollenites-3*
Fig. 9. *Alisporites grandis* (Cookson) Dettmann
Fig. 10. *Alisporites grandis* (Cookson) Dettmann
Fig. 11. 428 *Pristinuspollenites-1*
Fig. 12. 428 *Pristinuspollenites-1*
Fig. 13. 428 *Pristinuspollenites-1*
Fig. 14. *Podocarpidites radiatus* Brenner
Fig. 15. *Podocarpidites radiatus* Brenner
Fig. 16. *Cedripites cretaceus* Pocock
Fig. 17. *Podocarpidites multisimus* (Bolchovitina) Pocock
Fig. 18. *Alisporites bilateralis* Rouse
Fig. 19. *Alisporites bilateralis* Rouse
Fig. 20. *Podocarpidites multisimus* (Bolchovitina) Pocock
Fig. 21. 480 *Vitreisporites-1*
Fig. 22. 480 *Vitreisporites-1*
Fig. 23. 480 *Vitreisporites-1*

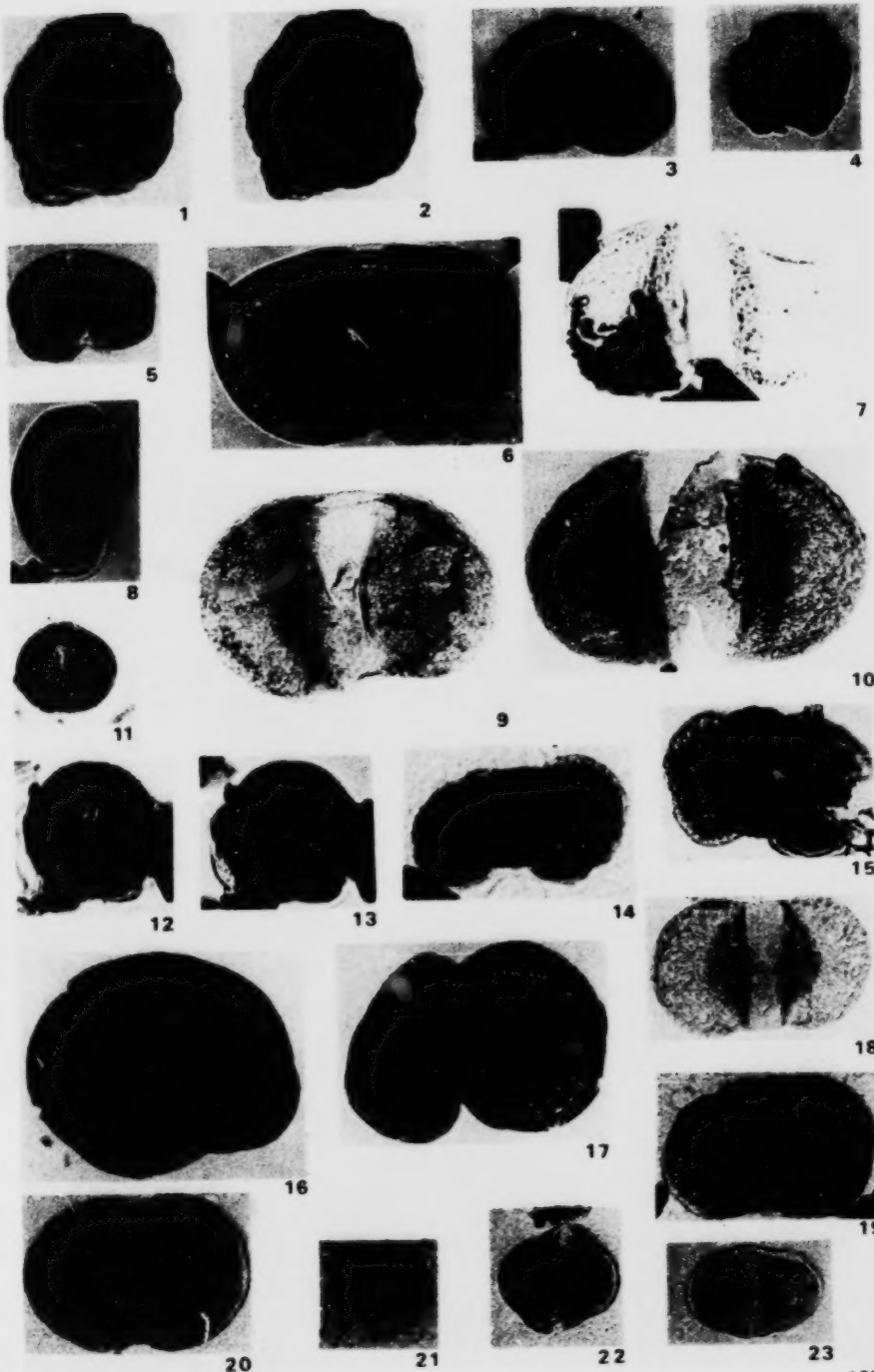
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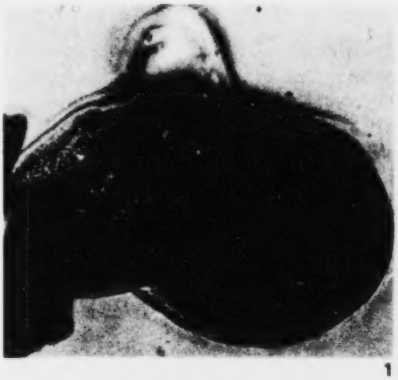
Plate 10 All figures 500X
Fig. 1. *Cedripites* sp. cf. *C. cretaceus* Pocock
Fig. 2. *Cedripites* sp. cf. *C. cretaceus* Pocock
Fig. 3. *Cedripites* sp. cf. *C. cretaceus* Pocock
Fig. 4. 492 *Pteruchipollenites-2*
Fig. 5. 492 *Pteruchipollenites-2*
Fig. 6. 492 *Pteruchipollenites-2*
Fig. 7. *Platysaccus megasaccus* Brenner
Fig. 8. *Platysaccus megasaccus* Brenner
Fig. 9. *Rugubivesiculites reductus* Pierce
Fig. 10. *Rugubivesiculites reductus* Pierce
Fig. 11. *Rugubivesiculites reductus* Pierce
Fig. 12. *Rugubivesiculites reductus* Pierce



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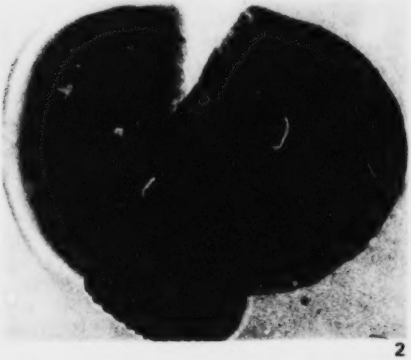

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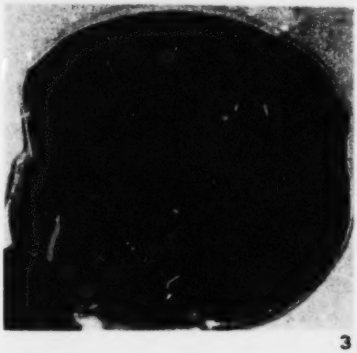

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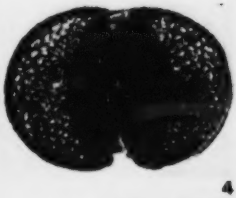

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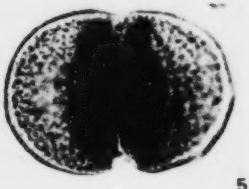

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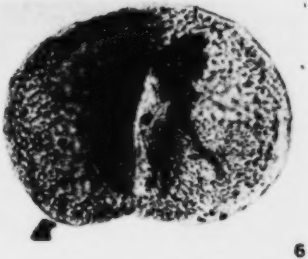

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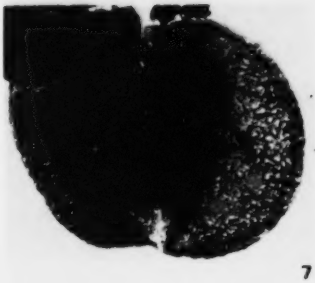

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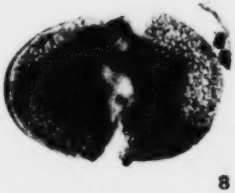

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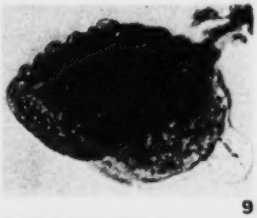

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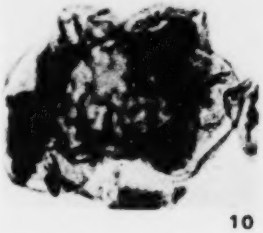

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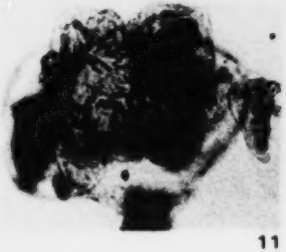

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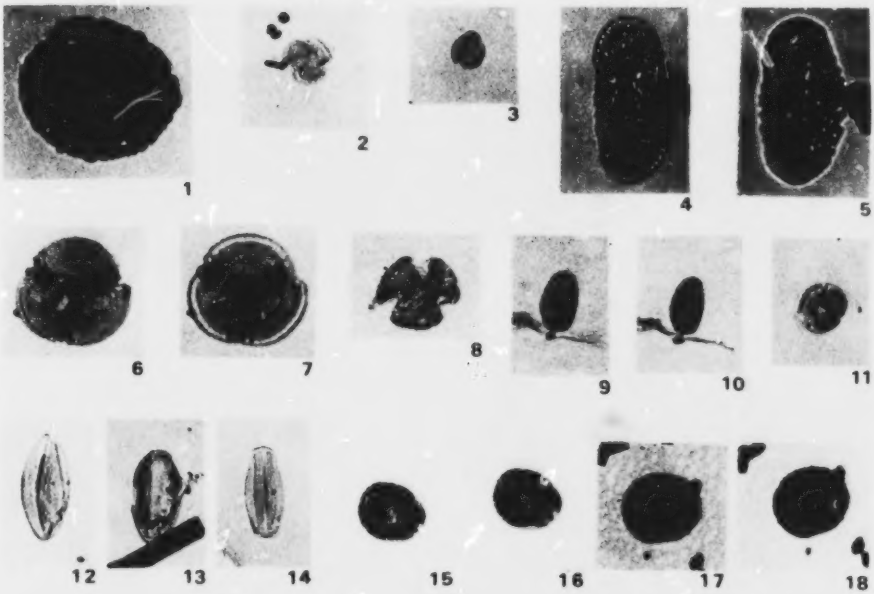
Plate 11 All figures 500X
Fig. 1. *Cerebropollenites mesozoicus* (Couper) Nilsson
Fig. 2. *Cupuliferoidaepollenites minutus* (Brenner) Singh
Fig. 3. *Cupuliferoidaepollenites minutus* (Brenner) Singh
Fig. 4. *Rouseia* sp. cf. *R. geranoides* (Couper) Srivastava
Fig. 5. *Rouseia* sp. cf. *R. geranoides* (Couper) Srivastava
Fig. 6. 444 *Phimopollis-1*
Fig. 7. 444 *Phimopollis-1*
Fig. 8. 444 *Phimopollis-1*
Fig. 9. 446 *Rouseia-1*
Fig. 10. 446 *Rouseia-1*
Fig. 11. 446 *Rouseia-1*
Fig. 12. 447 *Cupuliferoidaepollenites-2*
Fig. 13. 447 *Cupuliferoidaepollenites-2*
Fig. 14. 447 *Cupuliferoidaepollenites-2*
Fig. 15. 473 *Tricolpites-1*
Fig. 16. 473 *Tricolpites-1*
Fig. 17. 473 *Tricolpites-1*
Fig. 18. 473 *Tricolpites-1*
Fig. 19. 499 *Reticulatasporites-1*
Fig. 20. 499 *Reticulatasporites-1*
Fig. 21. 499 *Reticulatasporites-1*
Fig. 22. 499 *Reticulatasporites-1*
Fig. 23. 499 *Reticulatasporites-1*
Fig. 24. 499 *Reticulatasporites-1*
Fig. 25. 499 *Reticulatasporites-1*
Fig. 26. 499 *Reticulatasporites-1*
Fig. 27. 499 *Reticulatasporites-1*
Fig. 28. *Chromotriletes fragilis* Pocock
Fig. 29. *Schizosporis grandis* Pocock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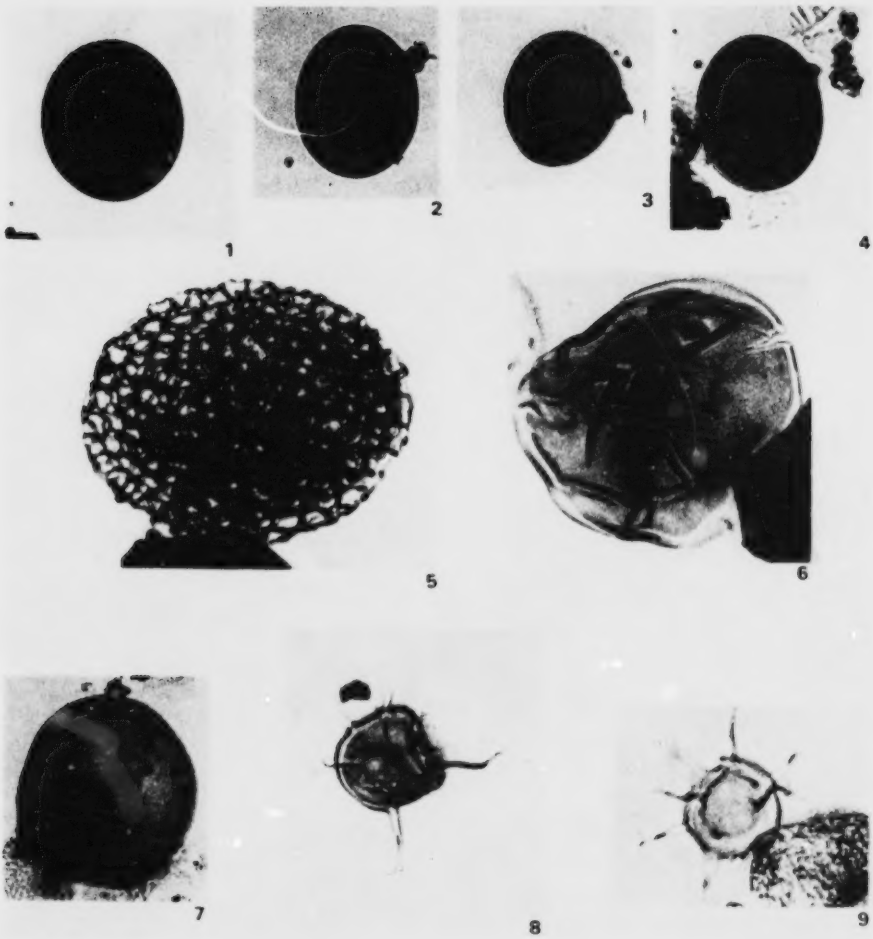

Plate 12 All figures 500X
Fig. 1. 442 *Fungus-1*
Fig. 2. 442 *Fungus-1*
Fig. 3. 442 *Fungus-1*
Fig. 4. 442 *Fungus-1*
Fig. 5. *Schizosporis reticulatus* Cookson and Dettmann
Fig. 6. *Schizosporis spriggi* Cookson and Dettmann
Fig. 7. *Schizosporis spriggi* Cookson and Dettmann
Fig. 8. M247 *Baltisphaeridium-4*
Fig. 9. M247 *Baltisphaeridium-4*

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Lignite and Industrial Mineral Resources of the Moose River Basin

by

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[1]Mineral Deposits Section, Ontario Geological Survey.

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ABSTRACT

Mineral deposit studies are concerned with deposits of lignite, quartz sand, kaolinitic clay and fireclay. The presence of gypsum, high calcium limestone, sand, gravel and peat is referred to. Lignite is more abundant than previously realized and a potential for discovery of additional lignite deposits is shown. Studies by the Ontario Geological Survey since 1975 have confirmed the widespread occurrence of glass-grade quartz sand, fireclay for high- to super-duty refractory ceramics and kaolinitic clay for production of whiteware and filler clays. The geologic history, formation and chemical and physical characteristics of the Cretaceous mineral deposits are discussed. Several of these deposits occur in Kipling Township (north of Kapuskasing) within 10 to 15 km of existing road facilities.

LIGNITE

Introduction

The presence of lignite in the Moose River Basin was noted by fur traders and explorers prior to the middle of the 18th century (Task Force Onakawana 1973). Outcrops of lignite in the banks of the Abitibi River at Blacksmith Rapids were officially recorded by Borron (1891) and J.M. Bell (1904). In 1926 when construction of the Ontario Northland Railway approached the area, the Onakawana lignite deposits were withdrawn from staking by the Ontario Government. The deposits were examined from 1927 to 1932 at which time the presence of 100 million tons of lignite with commercial potential was established (Task Force Onakawana, 1973, p.17).

In the years from 1939 to 1947 some coal was produced but no further activity is reported until, in 1966, Alberta Coal Company obtained an exploratory licence on 1025 km^2 including the lignite deposits. In 1978 the exploratory licence was succeeded by a 21 year lease to mine lignite from about 5184 ha at Onakawana granted to Onakwana Development Limited, a subsidiary of Manalta Coal Limited, itself a successor to Alberta Coal Company.

Lignite is known to occur in several outcrops in river beds of the Moose River Basin outside the Onakawana lignite fields. These outcrops have been discussed, amongst others, by McLearn (1927) who distinguishes 1) Mesozoic lignite seams, 2) Mesozoic clays with lignite and 3) Pleistocene lignite sands. None of the known occurrences, in McLearn's opinion, was sufficiently thick or consistent in lateral extension to be of economic importance but, in his words (1927, p.40c), "...it must be remembered that the Mattagami series is distributed, perhaps discontinuously, over a large area, all of which has not been

examined..." and "...that most of it is below river-level, hidden from observation; that the thickness is not known, and that little exploration by drilling has been done..."

Recent drilling sponsored by the Ontario Geological Survey in 1975 has indicated additional sections of sand and clay with lignite fragments. Massive lignite beds have not been detected.[1] In the event of massive lignite being present proper evaluation of such beds would require whole core sampling. Future drilling will be designed to allow, at least in part, for this method of sampling.

Formation of Lignite

Lignite or brown coal represents an accumulation of vegetative matter which has been subject to coalification. Coalification is a gradual process in which loss of volatiles (hydrocarbons)and relative increase of elemental, or "fixed" carbon leads to progressively higher ranking coal. In practice a distinction in coal is made between low ranking lignites with about 30 percent "fixed" carbon, intermediate bituminous coals and high ranking anthracites, with as much as 90 percent "fixed" carbon.

Geologic conditions conducive to accumulation of significant amounts of vegetative matter are abundant growth and poor drainage. By rapid burial under subaqueous conditions oxidation of the decaying plant material will be prevented. The required conditions are generally met in swamps or bogs which frequently owe poor drainage to a high clay content in the subsoil. The character of vegetative matter will vary according to the depth of water. Changes in water level may be reflected in the differences in beds of a single lignite deposit. In a deltaic environment favourable areas for plant accumulation will be found between major river courses. Thus, the identification of fossil river courses may assist in the determination of exploration targets for lignite.

Decomposition and coalification of vegetative matter makes it difficult to recognize the origin of individual components in lignite or coal. In coal a general distinction is made between anthraxylon, a translucent material with recognizable structures of plant tissue, and attritus, a disintegrated and partially opaque organic material.

Chemically the substance of lignite, in contrast to that of higher ranking coal, occurs for a large part in the form of humic acids. The difference shows when dissolving coal material in sodium hydroxide which yields a deep brown solution in the case of lignite. Humic acid can be precipitated from this solution by acidifying it with hydrochloric acid.

Humic acids are not defined by a single chemical formula. For certain forms of peat Edwards (1953, p.30) gives the formula: $C_{60}H_{52}O_{24}(COOH)_4$, corresponding to approximately 55 percent carbon by weight. Humic acids in lig-

[1] Additional lignite beds were encountered in government sponsored drilling in 1978 and 1981.

nite forming up to 60 weight percent of the substance (Edwards 1953, p.29), contain from 62 to 66.5 percent carbon. The material is described by Edwards (1953, p.29) as follows:

> The freshly precipitated and filtered humic acid is a swollen jelly like substance, that shrinks strongly and hardens in drying, when it can be crushed to a black, glistening powder. Dried in air it retains 20 percent moisture; completely dried out it is hygroscopic, indicating a relationship between the drying behaviour of brown coals, and their content of humic acid. The brown colour of the coal derives from these compounds.

In an analysis of lignite the moisture content is determined and values are given for ash, volatiles and fixed carbon. The sources of ash are detrital mineral matter (quartz, clay), salts (calcium, magnesium and iron sulphate solutions in pore water) and plant ashes. Detrital mineral matter tends to predominate near the edges and top and base of lignite seams while the centre is characterized by chemically derived ashes. Sulphur in lignite occurs in sulphates, (e.g. gypsum) in sulphides (pyrite, marcasite) and as elemental sulphur. The total sulphur content is variable and up to 9 percent has been recorded (Edwards 1953, p.56). The use of lignite ash for production of synthetic aggregate or as replacement of cement in concrete is being studied by several organizations in Canada and the U.S.A. Manz (1973,p.213) reports that in the near future up to 25 percent of the cement is expected to be replaceable by these ashes.

The physical characteristics of lignite partly determine the preferred method of mining. Lignite with more than 45 percent moisture can generally be excavated without the use of explosives. Upon exposure to dry air moisture content may be reduced to about 20 percent causing cracking and shrinkage at the surface of the coal. The drying process rarely advances more than a few inches from surface, however, and part of the lost moisture will be replaced in humid weather.

Exposure of lignite to air causes oxidation. Where large surface areas are involved, as in dust, oxidation may lead to spontaneous combustion. On the other hand fine coal dust is sometimes applied to a stockpile to prevent air circulation and consequently stop, for lack of oxygen, the internal heat buildup and spontaneous combustion. Paradoxically stockpile fires are sometimes initiated by rain showers because of the excess heat developed when internal capillary surfaces of lignite are wetted.

The capillary structure of brown coal affects the drying characteristics of the material. The fineness of the capillaries determines the strength of bonding of the capillary water. Conversely this knowledge is used to derive the capillary size distribution from the relationship of vapour pressure and moisture content of the lignite. The information is essential in understanding the resistance or amenability of the material to briquetting, which allows shipping of the partly dried lignite as an industrial or domestic fuel. Weaker briquettes, according to Edwards (1953, p.33,34), are thought to result from increasing fineness of the capillaries since resistance to compaction of the coal particles increases. In a study by Gauger (1932) referred to by Edwards (1953, p.34), it was found that in going from wood to peat the relative volume of large capillaries increases while further coalification results in a progressive decrease of this volume.

The Onakawana Lignite Fields

Lignite at Onakawana predominantly occurs in two seams in the Lower Cretaceous Mattagami Formation. Remnants of a third seam are present in high parts of the subcrop less affected by erosion. Smaller lignite beds often are found between the major seams.

The major lignite seams are largely continuous throughout the Onakawana area. They are primarily autochthonous deposits derived from local vegetation. It has been suggested (Dyer and Crozier 1933, p.57,61) that the existing 40 to 50 feet of compacted lignite required the accumulation of 300 to 400 feet of uncompressed vegetable matter and that differential movements responsible for the local basin shape were active at the time of deposition.

In a study based on the latest drilling, Trusler *et al.* (1974) distinguished the following units in the stratigraphic column:

1) Top Fireclay — volume insignificant due to erosion.
2) Top Lignite — volume insignificant due to erosion.
3) Upper Fireclay — frequent remnants in subcrop; total volume 11 million tons
4) Upper Lignite — unit largely continuous; mean thickness 17.56 feet (5.4 m); volume 50 million tons.
5) Middle Parting — Unit continuous; thickening westward due to increasing volume of sand and inclusion of up to 11 significant lenses of lignite; clay too thin to mine in eastern area and of doubtful quality in western part.
6) Lower Lignite — Unit continuous over most of 8 square miles (20.72 km^2) area; mean thickness 18 feet (5.5 m); volume 140 million tons.

Not all these units are uniformly present. Discrepancies are either due to depositional differences or subsequent erosion. The remaining lignite reserves are distributed over three areas: Main Field, East Field, and Portage Field (Figure 5.1). The outline of these fields is based on a ratio waste: ore $\leq$ 5.30:1 (Main and East Field, Trusler *et al.* 1974) or on major intersections of lignite in the drill holes (Portage Field).

Quaternary deposits overlying the Mattagami Formation at Onakawana are primarily responsible for the high waste to ore ratio. Up to 48.75 m thick (Shawinigan Engineering Company 1973, Vol. 11, 2-2) glacial and marine deposits overlie ore in some locations. Elsewhere, for example in the area separating Main and East Fields, pre-glacial erosion has allowed the glacial deposits to come in contact with basal clay underlying the lower lignite seam. A schematic representation in fence diagrams of the distribution of lignite in the two fields is given in Figures 5.2 and 5.3.

Based on an average strip ratio of waste: ore = 6.56, Shawinigan Engineering Company (1973, Vol.11, 2-3) calculated recoverable reserves in millions of short tons as follows:

Field	No.1 Seam	No.2 Seam	Total
Main	41.5	121.5	163
East	3.1	8.6	11.7
Portage	5.4	8.9	14.3
Total	50.0	139.0	189.0

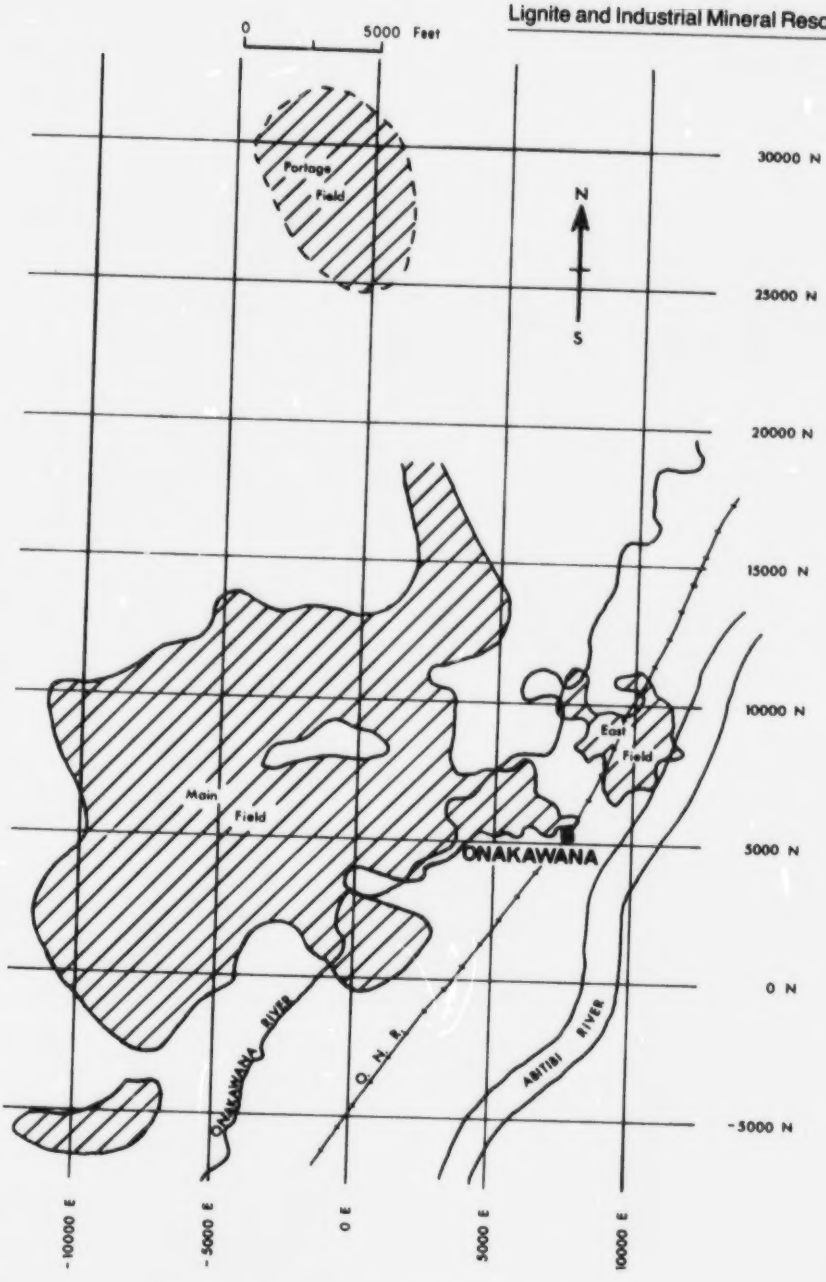

Figure 5.1–The Onakawana Lignite Fields.

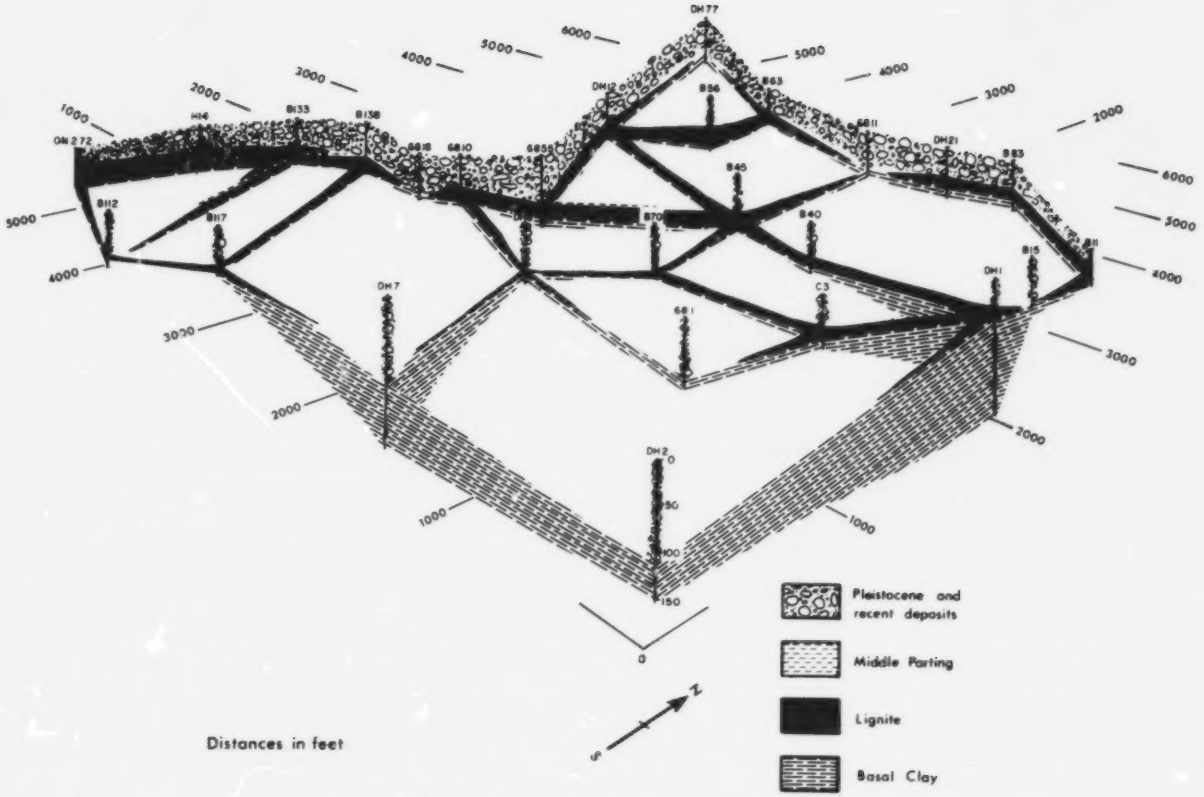

Figure 5.2–Fence Diagram, Onakawana lignite deposit, East Field.

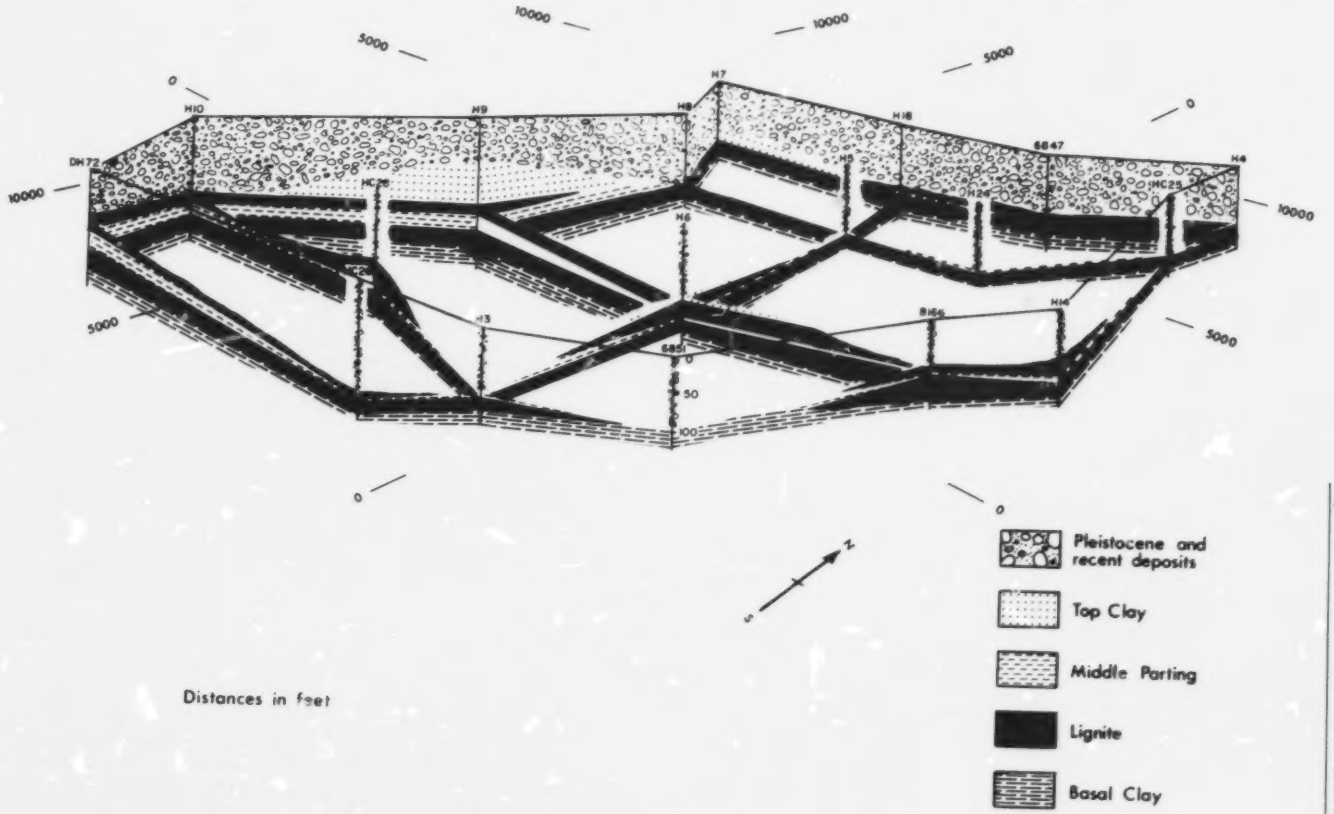

Figure 5.3–Fence Diagram, Onakawana lignite deposit, Main Field.

In samples of lignite from Onakawana the following entities were distinguished by Tasker (1933):

Woody: Definite pieces of wood, generally hard and laminated but often consisting of knotty portions. Many pieces show well bedded structure. The colour of the interior of the lumps is generally light chocolate-brown, though the outside is black. Most pieces when sufficiently dried show a slight lustre when broken across the bedding plane.

Peaty: As the name indicates, of a peat-like nature. Breaks up into flakes and often appears to be a mass of compressed leaves and twigs. This material contains large quantities of fusain or mineral charcoal.

Earthy: When wet, this material tends to pack into balls or lumps, but generally can be crushed by hand as soon as material dries out a little. The particles are usually spherical in shape and on drying produce a large amount of dust.

Briquetting tests of earthy lignites from Onakawana are described by Tasker (1933). It was found (Tasker 1933, p.28, 29) that dried material could be briquetted without a binder, but that the briquettes were not quite as weather resistant as is desirable for handling as a domestic or industrial fuel.

The quality of lignite at Onakawana is variable both within the field and between the upper and lower seams. Approximate average analysis of ore in situ (in percent by weight) is given by Shawinigan Engineering (1973, Vol.II, 2-4) as follows:

Average Analysis Lignite:

	Percent
Moisture	46.00
Ash	8.83
Volatiles	21.92
Fixed Carbon	23.25
Total:	100.00

Calorific value 5,246 B.T.U./lb.

These averages correspond to the following ultimate analysis:

		Dry, ash free
Carbon	32.23	(70.63)
Hydrogen	2.20	(4.82)
Sulphur	0.51	(1.12)
Nitrogen	0.23	(.50)
Ash	8.37	-
Oxygen	10.37	(22.73)
Chlorine	0.09	(.20)
Moisture	46.00	-
Total:	100.00	100.00

In their assessment of Onakawana lignite Shawinigan Engineering (1973, Vol. II, 2-4) allows for the following as delivered quality variance:

Quality Lignite as delivered:

	Daily Variance	Average
Dry Ash	27.0 - 13.0	20.9
B.T.U./lb.(dry)	8,320 - 10,120	9,075
Moisture %	55.0 - 42.0	46.00
B.T.U./lb. (wet)	3,744 - 5,840	4,900

Onakawana lignite, with an average calorific value of 4,900 B.T.U./ lb. (wet) is low rank by North American Standards but high grade by European standards where lignites with values as low as 1,800 B.T.U./lb. are used (Shawinigan Engineering Company 1973, Vol. I, p. 2).

Production proposals for Onakawana lignite have centred on open-cast mining and local power generating plants. Some production was achieved in the period of the Second World War (1939-1947). The pit is located in the East Field, adjacent to the Abitibi River. In 1942 the development was taken over from the Temiskaming and Ontario Northland Railway by the Ontario Government. Construction of a steam drying and process plant was completed in 1945. When an experimental run showed that inflammable dust created an explosion hazard further work was discontinued. As a last effort, stripping of overburden to make available an emergency supply of coal for the winter of 1946/47 was completed in 1946. Planning for development of the Onakawana Lignite Fields should include the use of fireclay, large quantities of which have to be moved in the process of excavating for coal. The clays range from a true ball clay to plastic refractory clay (Dyer and Crozier 1933, p.79-87). A supply of these clays from local sources is lacking in Ontario.

Other Lignite Occurrences

BIG BEND, MATTAGAMI RIVER

Lignite outcrops were reported on the east bank of the Mattagami River near Big Bend, about 12 km downstream from the Precambrian escarpment (Montgomery and Watson 1928, p.95; see also Figure 5.4, location 4). The deposits are primarily Mesozoic clays with lignite fragments, although in one location, 200 m south of the Kipling-Sanborn Township line, a 1 m thick massive "seam" was reported (McLearn 1927, p.40c) to be exposed over a distance of about 15 m. The total distance over which outcrops occur is approximately 0.5 km.

Clay beds in the lower part of the riverbank dip 80° east in some places. The inclination has been interpreted as a result of slumping from higher levels in the river bank (Keele 1920, p.45). Excavation and drilling in this area have shown that the disturbance is local, whether due to slumping, the effects of glaciation, or possibly, adjustment under influence of load differential between the river bank and the river valley.

Test results of samples of lignite from the outcrops are given in Table 5.1, samples 1, 2, and 3.

Excavation and drilling took place on the west side of the Mattagami River in the river bank opposite these outcrops (Figure 5.4, location 3). Grey and black clay with lignite fragments was encountered, according to Montgomery and Watson (1929, p.93, 94), at depths of 3.7 to 13.0 m and 18.5 to 27.0 m. Drilling was completed to a depth of 42 m without encountering further lignite fragments.

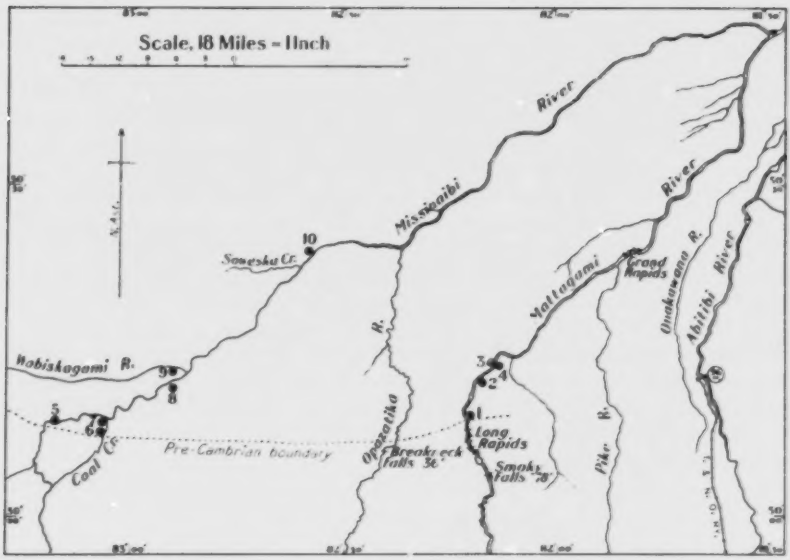

Figure 5.4–Map showing locations of fireclay and silica-sand outcrops.

TABLE 5.1 | ANALYSES OF LIGNITE ON DRY BASIS*.

Sample No.	Ash	Vol. M.	F.C.	S.	B.T.U.	Fuel ratio
1	21.9	38.5	39.5	0.4	9020	1.00
2	7.2	47.0	45.8	0.8	11160	0.97
3	57.1	26.8	16.1	0.5	3830	0.60
4	3.8	47.6	48.6	0.8	11570	1.00
5	21.2	42.3	36.5	0.7	8420	0.86

1. A sample across the 3-foot seam on the east bank of Mattagami river about 750 feet south of the Kipling-Sanborn line.
2. Lignitized tree trunks in the 0.6-foot "seam" on the east bank of Mattagami river, about 180 feet north of the Kipling-Sanborn line.
3. Matted lignitized vegetation in the above "seam".
4. Lignitized tree trunks from clays in No.2 McCarthy shaft.
5. Float lignite on lower part of Coal brook.

*after F. H. McLearn, (1926)

ADAM CREEK — KIPLING TOWNSHIP

Lignite fragments and lignitized tree stumps up to 0.3 m in diameter were found in grey Mesozoic clay in the west bank of the Adam Creek diversion channel and as float in the creek bed north of the Precambrian escarpment in Kipling Township. Detailed mapping of the creek bed is required to accurately locate the deposits (Telford, Vos, and Norris 1975, p.5) and recent fieldwork has identified several lignite outcrops (Telford and Verma 1978).

COAL RIVER — BURSTALL TOWNSHIP

Lignite has been reported in outcrop about 0.5 km upstream from where Coal River runs into the Missinaibi River (Montgomery and Watson 1929, p.95; figure 5.4, location 7). Discovered by R. Bell in 1878, the outcrop has since been obscured by slump or river deposits. Montgomery and Watson (1929, p.95) reported black clay with lignite fragments locally confined to the bed of the creek. An analysis of lignite fragments was given by McLearn (Table 5.1, Sample 5).

Black clay with lignite fragments was also reported from local drill intersections together with a 0.5 m lignite bed at about 6.75 m depth (Montgomery and Watson 1929, p.96).

PORTAGE ISLAND — SUTCLIFFE TOWNSHIP

The presence of lignite near Portage Island, approximately 14 km NNW of Onakawana, was reported by Dyer and Crozier (1933, p.78). A 0.5 m lignite seam underlies 5 m of dark grey refractory clay on the north bank of the Moose River about 950 m downstream from Portage Island. Some lignite associated with grey and black refractory clay can be seen in outcrop on the north bank opposite the foot of Portage Island. Holes drilled in this location, and in a gravel pit 550 m to the south, indicate lignite in two seams aggregating 4.6 m at depths of 10.0 to 17.5 m and 15.7 to 22.0 m. These seams appear to be extensions of the Upper and Lower Lignite at Onakawana.

BIG RAPIDS, MISSINAIBI RIVER — MCCUAIG TOWNSHIP

A lignite occurrence belonging to the Pleistocene lignitic sands variety is located just below Big Rapids on the boundary of Gentles and McCuaig Townships (McLearn 1926, p.40c). Lignite in this occurrence was characterized by McLearn (1926, p.40c) as follows: "The lignite fragments are well worn and their corners are rounded. They have evidently been derived from erosion of the grey clay facies of the Mattagami series. They have been transported and laid down in stream courses and in a sense might be considered as lignite gravels." The deposits are of little interest economically due to the lens-like nature of gravel deposits in general.

CHAUSSE CREEK, OPASATIKA RIVER — ACRES TOWNSHIP

Lignite occurs on the east bank of the Opasatika River, a little over 1.2 km above the mouth of Chausse Creek which joins the Opasatika from the southwest in the north-central part of Acres Township (McLearn 1926, p.41c). The deposit consists of thin layers of worn lignite fragments in sand, and according to McLearn it is interglacial or early Pleistocene, like that at Big Rapids on the Missinaibi River.

HAMBLY NO.1 DRILLHOLE — HAMBLY TOWNSHIP

Lignite fragments were encountered at depths between 123 and 157 m in an exploration well drilled in 1973 by Aquitane Sogepet *et al.* (1973) in the south-central part of Hambly Township. The following details were given by Beck (1975, p.92):

Lignite was noted intermittently in the drill core of the Hambly No. 1 well from depths of 123.0 to 157.0 m. Lignite occurs as thin layers in clean well sorted fluviatile quartzitic sand between 123.0 m and 126.0 m. Between 126.0 m and 157.0 m lignite occurs in trace amounts (up to 5%), along with minor pyrite and minor interbedded green shales, in medium-coarse grained quartzitic sand.

Location: NTS 42 J/7E, Latitude 50°17′North and Longitude 82°34′West.

Reference: Hambly No. 1 Well File, Permit No.3547, Petroleum Resources Section, Ministry of Natural Resources.

RANOKE DRILLHOLE 74-8 — HOGG TOWNSHIP

Lignite was intersected in thin layers from 32.5 m to 44 m in the northeast part of Hogg Township, east of the Mattagami River. The following details were given by Beck (1975, p.84):

NTS 42 I 5E; Latitude 50°25′; Longitude 81°45′

Lignite found as thin layers in dark green-grey and dark brown-grey fire clay of the Mattagami Formation, at a depth from 32.5 m to 44.0 m. Lignite is more abundant between 37.0 m and 44.0 m and is associated with silt. Between 44.0 m and 47.7 m, lignite seams are rare and associated with silt and sand. Drill holes on either side of Ranoke 74-8 failed to intersect lignite seams.

Reference: File No. 83-1-118, Aquitaine Company of Canada Limited, Assessment Files Research Office, Ontario Geological Survey, Ministry of Natural Resources.

Moose River Basin Studies 1975

Six holes drilled during winter 1975 by the Ontario Geological Survey (Rogers *et al.* 1975; Telford, this report) encountered traces of Mesozoic lignite.

DRILLHOLE 75-01

Lignite fragments were encountered at depths from 14.8 m to 19.7 m in drillhole 75-01, Soweska River, in the northwest corner of Hambly Township (see Figure 1.3). The lignite fragments occur in association with grey clay and with fine quartz sand within 6.7 m of the contact with overlying glacial till. The lignite-bearing beds are underlain by at least another 26.5 m of quartz sand, kaolinitic clay, and fireclay devoid of lignite. The hole was abandoned, at a depth of 46.0 m, due to sanding of the rods.

DRILLHOLE 75-02

A few peaty wood chips were found in drillhole 75-02 (25 km north-northwest of drillhole 75-01) in coarse quartz sand at a depth of 103.5 m to 104.8 m. The sand occurs within 3.0 m of the contact with overlying glacial till, between 1.0 m of brown clay immediately above, and 0.5 m of hard, bluish white clay immediately below the sand.

DRILLHOLE 75-03

The upper 8.3 m of Mesozoic sands and clay in drillhole 75-03 (40 km north-northwest of drillhole 75-01), at a depth of 115.0 m to 123.4 m, contain fragments of lignite. From 115.0 m to 119.4 m, the beds are primarily sandy, while in the lower part (119.4 m to 123.4 m) lignite is associated with beds of green and grey to black clay. At least another 12.0 m of red, brown, and green clays devoid of lignite underlie these beds. See Telford (this report) for a stratigraphic classification of these units.

DRILLHOLE 75-04

Fragments of lignite occur in glacial till in drillhole 75-04 (12 km north-northwest of drillhole 75-01) at depths of 76.6 m to 79.7 m, 87.1 m, 88.0 to 89.5 m and 103.4 m to 106.5 m. These sections are part of a larger section of till underlying 26.8 m of clay and other till near the surface and underlain by additional till and stratified sediments to a depth of 155.7 m. Mesozoic sands underlying these glacial deposits, at least to a depth of 166.9 m, show no trace of lignite. It must be assumed that the lignite fragments in the till derive from now eroded overlying Mesozoic deposits or otherwise from underlying deposits elsewhere.

The hole was abandoned, at a depth of 166.9 m, due to plugging of the rods with coarse sand. (Rogers *et al.* 1975). The extreme depth (155.7 m) to which glacial deposits extend suggest that they locally fill an old river channel.

DRILLHOLE 75-05

Twigs and peaty wood chips occur in Mesozoic clay in drillhole 75-05, Waboose River, east-central part of Acres Township. Clay is predominant to a depth of 57.5 m underlying 22.5 m of glacial deposits. The remnants of wood are confined to a small section of sandy, dark grey clay at a depth of 40.6 m. The hole was abandoned in Mesozoic quartz sand at a depth of 88.6 m due to sanding of the rods.

DRILLHOLE 75-06

Drillhole 75-06 drilled on the east bank of the Opasatika River near the center of McCausland Township intersected 52.3 m of Pleistocene formations, 88.9 m of Mesozoic sands and clays (see Telford, this report), and 35.2 m of Devonian clay, shale, and limestone. The log of drillhole 75-06 notes the occurrence of peaty wood chips or dark wood fragments in several instances but the presence of lignite is recorded only at depths of 90.0 m or lower. The log from 90.0 m to 93.2 m reads:

90.0 m - 90.3 m	gravel layer with coarse lignite ? fragments
90.3 m	fine sand and silt as above
90.8 m	coarse sand, some clay, lignite ? fragments, minor silt and fine sand
92.3 m	silty, sandy, pebbly gravel, a few small cobbles, mostly limestone
93.2 m	lignite cobble (aluminum foil, sample 090)
103.8 m - 106.2 m	fine pebbly gravel, medium sandy matrix with 0.3 m thick layer of peaty Lignite;
106.9 m - 107.2 m	medium fine sand, with peaty lignite, some clasts
107.2 m - 110.2 m	fine pebbly sandy gravel, medium sandy matrix, organic detritus and several thin lignite layers as shown
110.3 m - 111.6 m	medium fine sand, with organic detritus, peaty lignite layer as shown; coarsens downward into a fine pebbly gravel with a medium fine sandy matrix

The bulk of sediments in these intersections are pebbly gravels in which lignite fragments represent allochthonous deposits. At greater depth in the Mesozoic section (127.4 m to 141.2 m), clay prevails. The clay is overlain by a "wood lignite layer" at 127.2 m to 127.4 m. Whether or not this layer or the lignite laminae occurring at 124.5 m depth are possibly autochthonous cannot be ascertained from samples obtained by the reverse circulation drilling method which yields chip samples only.

Lignite Potential of Moose River Basin

In an evaluation of lignite potential of the Moose River Basin it is necessary to consider various parameters. Beginning with the overall size of the area underlain, or rather, expected to be underlain by Mesozoic sediments, an upper limit is immediately imposed. This area is presently considered to be of the order of 7000 km^2. The particular basin configuration required to allow protected growth and accumulation of vegetative matter protected from erosion, dilution with inorganic matter, or introduction of oxidising fresh water currents, further limits the scope for significant lignite deposits. Assuming that major river courses of the pre-Pleistocene period were comparable in number and size to the present ones the area favourable for lignite deposition remaining is about 2,000 km^2.

The chance of lignite accumulation actually having occurred in favourable areas must be estimated conservatively in view of the failure, thus far, to detect any significant deposits outside Onakawana. If estimated to be limited to 10 percent then a mere 200 km^2 remain.

The effect of fossil river courses is twofold. At the time of accumulation, major rivers would have impeded continuous accumulation in their immediate environment. Subsequent to their period of accumulation lignite deposits became subject to erosion, particularly when in the path of major streams. Such streams may have altered their courses frequently in the areas underlain by unconsolidated Mesozoic sediments. The aggregate effect reduces the lignite potential of the Moose River Basin, bringing the area in which significant lignite deposits are estimated to occur to below 200 km^2. The possibility that erosion of deposits has caused potentially economic accumulation of lignite elsewhere, as lignite gravel, is remote since existing lignite gravels show a high ash content due to admixed mineral matter.

The Onakawana deposits occur in two to three separate layers with an aggregate average thickness of 10 m. The geological parameters determining accumulation, whether linked to basin subsidence or sea level rises, are not sufficiently well known to speculate on the possible thickness of deposits elsewhere. It is prudent to consider thicknesses encountered at Onakawana as maximum for the Moose River Basin as a whole. In view of the marginal economic feasibility of developing the Onakawana deposits which occur adjacent to an established railway line it may be reasoned that the area required for deposits elsewhere, in order to be economic, needs to be much larger. This condition applied to a potential total area of 200 km^2 reduces the estimated maximum number of significant lignite deposits to:

$$\frac{200}{2 \times \text{area Onakawana deposits}} = \frac{200}{2 \times 21} = 4.8$$

The possibility of finding a deposit of the size of Onakawana by drilling has been estimated to have 90 percent chance of success when about 400 holes are drilled over the entire basin. (T. Pauk, Ontario Geological Survey, personal communication). In view of the ⅔ reduction in basin area since 1974, the equivalent number of required holes is now 266. It is obvious that at this stage much

more is to be gained from geological reconnaissance which, through better understanding of the geology, will lead to delineation of the areas with lignite potential, thus reducing exploratory drilling to the estimated 200 km^2 of potential lignite deposits. This will reduce the area of exploratory drilling to 1/35 (200 km^2), of its present size (7,000 km^2), and the number of required exploratory holes accordingly to seven or eight holes, or less if the area of interest is of necessity larger than the Onakawana lignite area.

INDUSTRIAL MINERALS

Introduction

Industrial mineral resources of economic interest in the Moose River Basin include the Devonian high-calcium limestones, the Middle Devonian gypsum deposits, Mesozoic quartz sands and kaolinitic clays, and Quaternary deposits of gravel and peat. Gravel deposits will be of importance locally in areas where construction of roads or railways is contemplated. The potential importance of peat deposits is less predictable, but successful development of Onakawana lignite as a fuel for power generation will undoubtedly attract more attention to extensive peat deposits known to exist in the James Bay Lowland area. High-calcium limestone of Devonian age has potential importance as a flux stone or as chemical stone in future industrial developments, or as the basic raw material for cement production. It could provide pulp and paper manufacturers with their needs of high-calcium lime or limestone from local sources. According to Goudge (1938, p.322) 31 feet of high-calcium limestone (>95% $CaCo_3$) are exposed in a section at Coral Rapids. Gypsum deposits in the Moose River Basin provide spectacular outcrops of white rock along the Moose and Cheepash Rivers, 64 km southwest of Moosonee. A description of these deposits with literature references was given by Guillet (1964). A calculation based on the descriptions shows that a total of 180 million tons may be accessible in areas underlying the outcrops. If the area between outcrops is included a total of 6 billion tons of gypsum may be involved.

In the Mesozoic Era limited deposition of sand and clay took place in parts of the drainage basin of the Moose River. These continental deposits are of deltaic character and occur below the present elevation of the Precambrain escarpment which is the southern limit of the James Bay Lowland. Also present are accumulations of lignite representing swamp vegetation. The deltaic sediments were subject to extreme weathering which led to characteristics of economic significance. Weathering, combined with sorting of sediments during water transport, has produced deposits of almost pure quartz sand and kaolinitic clay.

In 1975 a program of drilling and geophysical studies of the Moose River Basin was commissioned by the Ontario Division of Mines. A refraction seismic and resistivity survey and reverse circulation chip drilling (6 holes) were conducted along 110 km of winter road north-northwest of Smoky Falls (see Figure 1.5). The results are expressed in a profile of geologic formations along this road

shown in Figure 2.11.

Examination of outcrops in Adam Creek, east of the Mattagami River in Kipling Township, established the occurrence of quartz sand-kaolinitic clay and fireclay deposits in this area (Telford *et al.* 1975). Drillhole samples were analysed by staff of the Geoservices Section, Ontario Geological Survey. Composite samples of quartz sand and associated clays, representing drillhole sections shown in Figures 5.5 to 5.8 were described and tested for size distribution, mineralogy, chemical composition, and physical characteristics.

The presence of kaolinitic clay in quartz sand was qualitatively established in samples of water flushing the drill chips to surface in reverse circulation drilling. Otherwise the -325 mesh fraction in all but one composite sample of sand was found to be fine quartz silt. The exception was sand 4 (Figure 5.5) in which an appreciable amount of chlorite, illite and expanding clay occurred.

Geology

Little is known about the disposition of the pre-Mesozoic erosion surface in the Moose River Basin. The underlying Paleozoic strata generally dip from 3° to 5° towards the centre of the basin but changes due to local folding are common. In the Coral Rapids area, local folding is probably associated with intrusion of post-Middle Devonian lamprophyre and kimberlitic dikes and sills (Bennet *et al.* 1967, p. 31). The Grand Rapids area, on the Mattagami River, has reversed dips ascribed by Martison (1953, p. 54) to a gently undulating basement floor. Sections obtained by drilling and geophysical surveys, done during the winter of 1975, showed a generally flat, near-horizontal Paleozoic surface. In detail, this surface is dissected by occasional faults with a vertical displacement of up to 40 m. The faults were detected in seismic and resistivity profiles and are postulated to intersect both the Paleozoic and Precambrian surfaces. Their strike was not determined.

To the south, the Paleozoic surface dips downward towards the Precambrian escarpment. The escarpment is the topographic expression of an older, east-trending fault zone which controlled deposition of Paleozoic and younger rocks in the southern part of the basin (Bennet *et al.* 1967, p. 31). It occurs at an elevation of approximately 155 m above sea level, and its location is marked by falls and rapids in the river courses.

The present surface of the Moose River Basin slopes gently towards James Bay. Near the Precambrian escarpment which occurs approximately at 155 m a.s.l., river valleys approach elevations of 91 m. A gradual decrease of elevation occurs between here and the coast. In a distance of approximately 240 km the decrease amounts to an average of 0.4 m per km for the large rivers, and approximately 0.6 m per km for the land in between. Under these conditions drainage is so incomplete that most of the area consists of muskeg, bog and swamp, with islands of wooded terrain in between.

Major deposits of quartz sand and vari-coloured fireclays are found in the Mattagami and Missinaibi River area immediately north of the Precambrian escarpment (see Figure 5.4); other deposits underlie a smaller basin at Onakawana. The Onakawana basin is limited by the Grand Rapids Arch to the south-

west and by outcrops of the Precambrian Shield to the east (see Figure 2.1). The depositional environment of Cretaceous sediments differed in the two basins on either side of the Grand Rapids Arch. The differences are accentuated by the predominance of lignite deposits in the Onakawana area. Preservation of lignite requires a reducing environment such as that obtained in a closed-in area with stagnant ground-water conditions and lack of ventilation. Such conditions apparently prevailed at Onakawana where the fireclays associated with lignite beds are of a dark grey colour. An association of quartz sand and kaolinitic clay seems to be lacking at Onakawana although some clays become sandier in a westward direction approaching the Grand Rapids Arch (Trusler *et al.* 1974).

In the area southwest of the Grand Rapids Arch, thick deposits of white quartz sand and kaolinitic clay alternate with beds of vari-coloured fireclay including bright red, buff, white, purple and grey clays, and occasional seams of lignite. The deposits discordantly overlap subcrops of Middle and Upper Devonian Formations and rest directly on Precambrian rocks in the escarpment area. In one location along the Mattagami River south of the escarpment a "... highly kaolinized syenite gneiss occupies the bottom of a ravine..." (Cross 1920, p.17). Deeply weathered crystalline rocks south of the escarpment have provided the source of kaolinitic clay and quartz sand of the Moose River Basin. In the deltaic environment north of the escarpment, fast flowing currents deposited coarse, pebbly sands in riverbeds while clays were carried into adjacent lagoons or oxbow lakes at times of flooding.

At the time of deposition the lateral distribution of Mesozoic sedimentary rocks was governed by the prevailing river system. Traces of this system have no doubt been preserved in the topography of the Canadian Shield south of the Precambrian escarpment. Unravelling of the drainage history of this area requires a detailed geomorphologic study. The results may show, for example, whether or not the broad indentation in the 700-foot topographic contour between the Missinaibi and Mattagami rivers indicates that previously a major river took the approximate course of the present Opasatika River. Such information would enchance the intelligent planning of bore hole locations in the Moose River Basin.

Drill information obtained along the Missinaibi and Mattagami Rivers has shown that, in places, clay beds are remarkably flat lying and persistent over distances of 1.5 km to 2.5 km at least. In lagoons of this size the character of the clay deposits will have been determined partly by the screening effect of vegetation and will vary accordingly from edge to center of the lagoon. Vegetation may also have affected subsequent alteration of the clay. Plant root systems tend to withdraw alkalis while humic acids react with soil components, washing away the fluxing elements to produce refractory clay. One theory holds the former process responsible for development of a particularly refractory clay, referred to as underclay, found under coal measures. Thick sections of fireclay were reported from a location on Coal River, between the Precambrian escarpment and the Missinaibi River, and from an area on the Mattagami River 9.5 to 11 km north of the escarpment (Montgomery and Watson 1929, p.82). On Coal River at least 6 m of black, brown and grey clays were reported. In the Mattagami River section 28 m of similar clays were found between depths of 9 m to 37 m. In both areas, some lignite occurs in association with black clays.

Fireclay deposits of this magnitude, basically kaolinitic clays with a

greater amount of organic impurities than the white clays, are less likely to have been affected by post-depositional weathering than kaolinitic clays associated with quartz sand. The latter kaolinitic clays may well be due entirely to post-depositional weathering of the feldspathic component of the sands. Under these circumstances individual beds of kaolinitic clay may result from minor washing and transport at surface or they may be due to vertical migration of fine clay particles through the sand and concentration at certain levels. The latter process is believed to have been responsible for beds with 92 to 93 percent kaolinite in residual deposits in North Carolina (U.S. Bureau of Mines Bull. No.53, 1913, p.16).

Silica Sand

Weathering of rocks and transport of the weathered material leads to accumulation of weathering-resistant particles. The accumulation may occur at the site of weathering or weathering-resistant particles may be washed away by rain or flood waters and selectively deposited downstream. If quartz is the predominant weathering resistant mineral in the original rock, the resulting sediment is a nearly pure quartz sand. Quartz is a ubiquitous mineral. In granite the quartz content often ranges from 20-35% (Hewitt 1972, p.57), and it is particularly abundant in rhyolites, granites, granite-gneisses and clastic sediments. Quartz, with formula SiO_2, hardness 7 (Moh's scale), and specific gravity 2.65, lacks cleavage. Prolonged physical abrasion results in perfect rounding of the grains. Quartz is insoluble in acids except hydrofluoric acid. It is constant in composition and, by nature, of high purity.

In source rocks quartz occurs in a wide range of grain sizes, from large bodies measured in metres in pegmatites to the size of rock flour in the clay fraction of sediments. Deposits of quartz sand are characterized by a specific grain size distribution corresponding to their origin. The effective grain size is occasionally influenced by cementing of the sand grains. The cementation agent may be silica or carbonate. Silica cement permits the use of sandstone as a source of lump silica required for the manufacture of ferrosilicon.

SILICA SAND – KAOLIN CLAY ASSOCIATION

Unconsolidated quartz sands associated with kaolinitic clay are frequently of high purity (<2% impurities). The weathering process responsible for kaolinization has simultaneously depleted the deposit of iron, magnesium, calcium, and alkalies, particularly in areas where kaolinization is complete. The major remaining source of impurities is a residue of heavy minerals, e.g. rutile, zircon, magnetite, staurolite. Heavier than quartz, some of these minerals have been incorporated in lighter grains or failed to respond to gravity separation over the distance of transport from the source rock. This distance is characteristically short for material in a quartz sand - kaolinitic clay association.

Size sorting of quartz grains is also a function of the distance of transport.

TABLE 5.2 | CANADA, AVAILABLE DATA ON CONSUMPTION OF SILICA, BY INDUSTRIES, 1975-76, (FROM PEARSE, 1977).

	1975	1976
	(tonnes)	
Smelter flux[1]	1 496 165	1 328 677
Glass manufacture (incl. glass fibre)	684 210	740 427
Foundry sand	677 886	577 455[e]
Refractory brick	239 352	280 090[e]
Artificial abrasives	137 632	143 895[e]
Fertilizer stock, poultry feed	14 939	54 351[e]
Chemicals	16 977	19 966
Concrete products	11 168	12 064
Gypsum products	8 659	8 932
Other[2]	223 800	209 019
Total	3 510 818	3 373 876

Source: Statistics Canada for source data. Compiled by Mineral Policy Sector, Department of Energy, Mines and Resources, Ottawa.

[1]Producers' shipments of quartz and silica for flux purposes.

[2]Includes asbestos products, ceramic products, soaps, frits and enamels, paper and paper products, roofing, silica brick and other minor uses.

[e]Estimated.

Consequently, a wide range of grain sizes is to be expected in deltaic deposits. Silica flour may be present as a result of disintegration of feldspar crystals with a fine intergrowth of silica or it may be a natural component of a clastic source rock. A wide range of grain sizes allows for development of glass-grade silica in conjunction with development and beneficiation of the kaolinitic clay component.

Analyses of some samples of quartz sand-kaolinitic clay from McBrien Township, James Bay Lowlands were published by Smith and Murthy (1970, p. 807). Of 21 samples, 56.2 percent of the material was in the size range (-20 + 140 mesh) of commercial glass sand. In this range, sizes were distributed as follows:

Size	Percentage
+ 20 mesh	0.8
-20 + 35	3.4
-35 + 45	5.9
-45 + 60	27.5
-60 + 80	41.2
-80 + 100	13.2
-100 + 120	5.5
-120 + 140	1.2
-140	1.3

With magnetic beneficiation it was possible to reduce the iron content to a range of 0.01 - 0.015 percent and an analysis of beneficiated sand (Smith and Murthy 1970, p.808) is given below:

SiO_2	99.73%
Al_2O_3	0.10
CaO_2	0.03
MgO	0.009
TiO_2	0.013
ZrO_2	0.009
Total	99.89%

Similar results were obtained from analysis of sands in Kipling Township. A report filed with the Ontario Division of Mines, (Ministry of Natural Resources File No. 83.1-37, Assessment Files Research Office, Toronto) by Chesterfield Mining and Exploration Company Limited described 29.25 m of quartz sand and kaolinitic clay intersected in a vertical diamond drill hole on the east bank of the Mattagami River, approximately 1.3 km north of the northermost hydroelectric dam and 61 m east of the river. The -20 mesh fraction of a sample of washed sand showed 97.8 percent $SiO_2$and 0.09 percent Fe_2O_3. This report, (p.19) foresaw no difficulty in producing a "totally acceptable glass sand" from this deposit, if production is achieved. It also stated (p.6) the loss of a large portion of kaolinitic clay which is washed out by the time the core sample is brought to the surface, thus impeding proper evaluation of the deposit.

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A discrepancy exists between visual estimates of quartz content of sand samples and chemical determination of silica content. With the exception of one sample (sand 4), laboratory values are lower than visual estimates. This is mainly due to the presence of fine grained carbonates, which in visual examination are included with quartz. The analyses are accurate to within ±2 percent and the results generally fall well within this range. For detailed analytical results see Vos (1978).

DRILLHOLE 75-01

Location	North bank of Soweska River, near northwest corner of Hambly Township
Depth	46 m
Log	Pleistocene 0-13 m Mesozoic 13-46 m

Depth of geophysical marker horizon (top of Paleozoic) 152 m

The upper 15 m of Mesozoic sediments in drillhole 75-01 (Figure 5.5) is predominantly white quartz sand with transparent, subangular grains of medium

to coarse grain size. Minor amounts of clay are interbedded. Samples 1 to 3 represent all but 0.5 m of this 15 m intersection. The sand is rather coarse for purposes of glass manufacture. In view of the content of clay and fine carbonates it may be expected that washing and sieving will raise the silica content considerably. Other impurities consist of amphibole, chlorite, pyroxene, garnet, zircon, and siderite. Muscovite is present in sample 2 and some fragments of greenstone occur in the upper part of the section (sample 1).

Beneficiation, e.g. heavy mineral separation and/or magnetic separation, will be required to further raise the silica content, and reduce the content of iron, titanium, and chromium. In glass sand the maximum permissible content of chromium is 6 p.p.m. and of cobalt 2 p.p.m. The measured quantities are equal to or only slightly in excess of these specifications.

Sands intersected in drillhole 75-01 are comparable to material found in Algocen No. 1 Deposit, McBrien Township, 28 km southwest of this location.

DRILLHOLE 75-02

Location:	26 km north-northwest of drillhole 75-01
Depth:	130 m
Log:	Pleistocene 0 - 100.5 m
	Mesozoic 100.5-124.5 m
	Paleozoic 124.5-130 m

Two samples of sand (Figure 5.5) taken from 100.5 to 103.5 m (sand 4) and 113- 120 m (sand 5) show that the material has little potential for glass production. Sand 4, a medium brown sand with transparent, fine to medium sized, sub-rounded quartz grains has an insufficient percentage of required grain sizes, a high iron content and 32 p.p.m. chromium. Sand 5, a white sand with transparent to frosted round grains, has a much better grain size distribution. Carbonate fines and high iron content detract from its value however.

Deep burial (>100 m), limited thickness (24 m), and absence of kaolinitic clay or fireclay are a major economic disadvantage of Mesozoic sediments at this location. The nature of the clays (illite, montorillonite) suggests that the sediments below 107.7 m belong to the less thoroughly weathered Middle Jurassic Mistuskwia beds rather than the Lower Cretaceous Mattagami Formation.

DRILLHOLE 75-03

Location:	39 km north-northwest of drillhole 75-01
Depth:	134.5 m
Log:	Pleistocene 0-116.3 m
	Mesozoic 116.3 - 134.5 m

Depth of geophysical marker horizon (top of Paleozoic) 220 m.

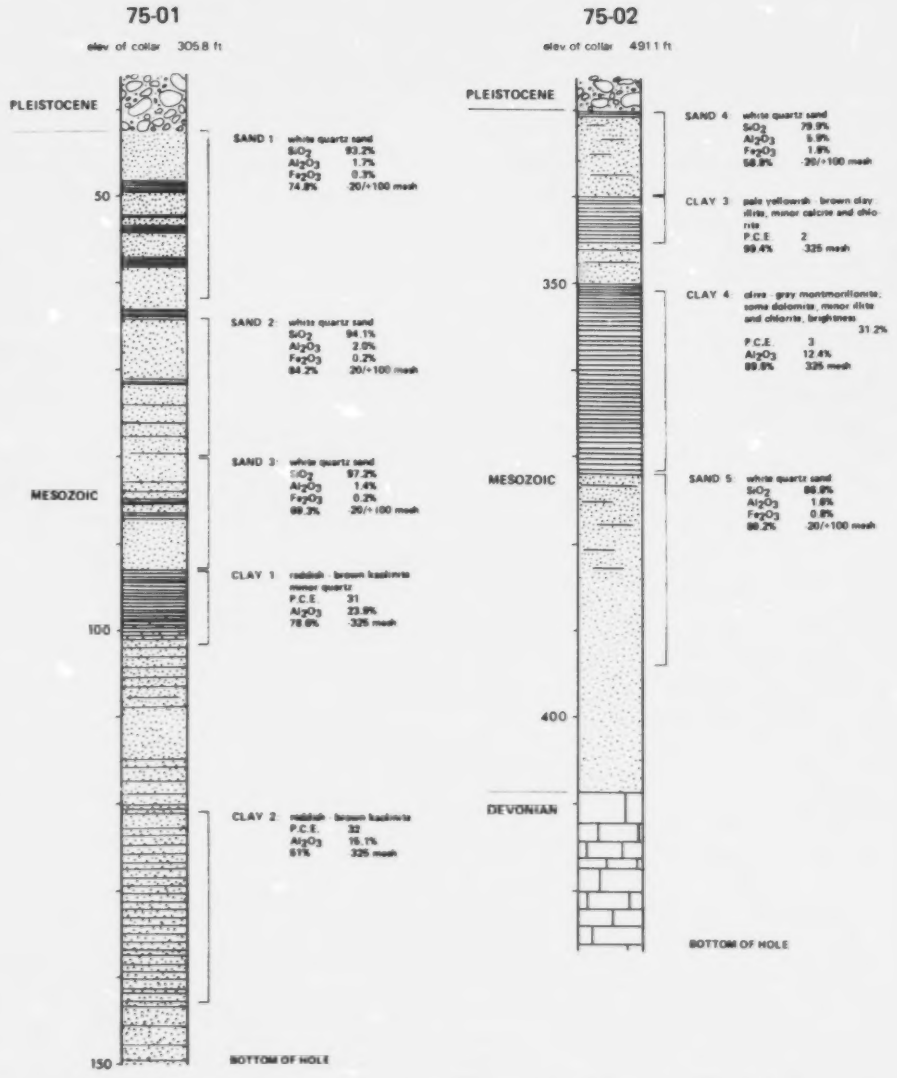

Figure 5.5–Analyses of composite sand and clay samples, drillholes 75-01 and 75-02.

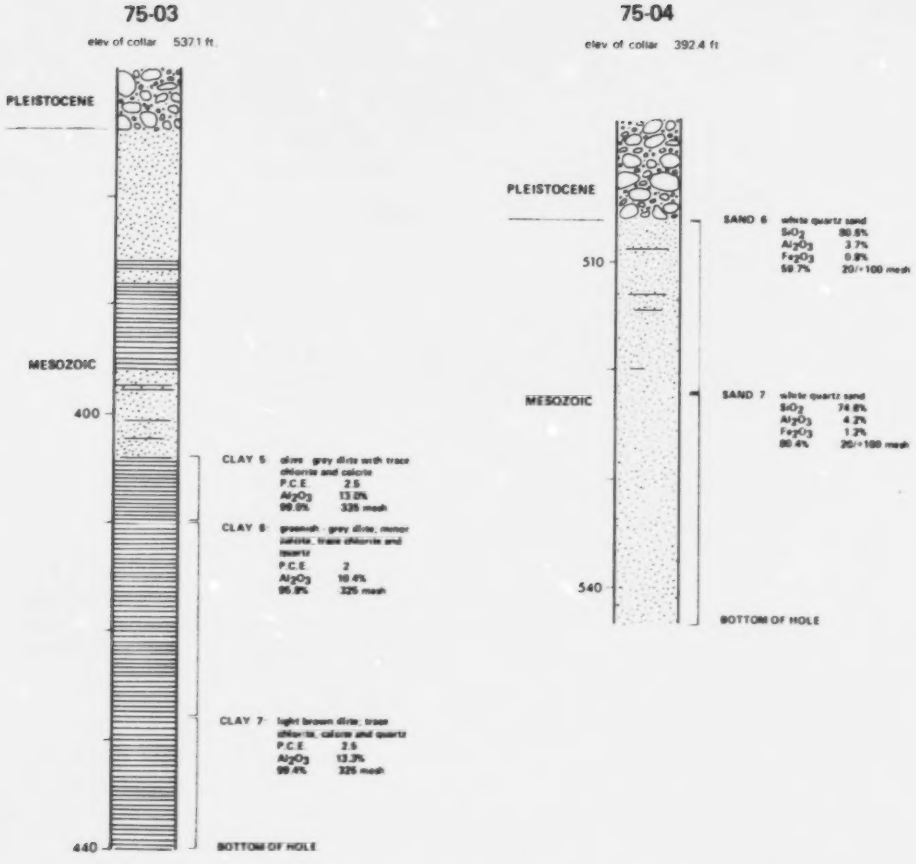

Figure 5.6–Analyses of composite sand and clay samples, drillholes 75-03 and 75-04.

Sands (Figure 5.6) in this hole (116.3-123 m) have not been analysed for economic potential. Depth of overburden impurities (lignite, pyrite), content of clay (illite), and remoteness of location all detract from their potential value, making economic analyses redundant at the present time.

DRILLHOLE 75-04

Location:	13 km north-northwest of drillhole 75-01
Depth:	165 m
Log:	Pleistocene 0-154 m
	Mesozoic 154-165 m

Depth of geophysical marker horizon (top of Paleozoic) 173.5 m.

Two samples (sand 6 and 7) represent the total intersection of Mesozoic sediments in this hole (Figure 5.6). The white quartz sands consist of angular, transparent quartz grains. The composite samples have a wide spread of grain sizes including an appreciable amount of carbonate fines. The content of iron (Fe_2O_3:0.80-1.20%) and chromium (10-18 p.p.m.) is high. The sands will require a great deal of beneficiation to qualify as glass sand.

DRILLHOLE 75-05

Location	Acres Township, east half, 4 km north of Precambrian escarpment and 2.5 km west of Kipling Township boundary.
Depth	88 m
Log	Pleistocene 23.1 m
Mesozoic	23.1-88.0 m

Depth of geophysical marker horizon (top of Paleozoic) 167.50 m.

Five samples of sand (Figure 5.7) represent depths of 26 to 32 m (sand 8), 57 to 65.5 m (sand 9), 65.5 to 74.5 m (sand 10), 77.7 to 83.8 m (sand 11) and 83.8 to 88 m (sand 12) or a total of 34 m in a 64.9 m intersection of the Lower Cretaceous Mattagami Formation. The sands are white with transparent to translucent, subangular to subrounded quartz grains.

Clay samples in this intersection show an abundance of kaolinitic clay which also occurs in association with the sands. Other impurities are: some red garnet, muscovite and biotite, and minor siderite, magnetite, ilmenite, pyrite and lignite. Very little carbonate or feldspar is indicated by the chemical analyses leaving clay, primarily kaolinitic clay, as the major impurity. Separation of clay by washing should raise the silica content sufficiently for use as glass sand. Further beneficiation will be necessary to reduce the iron content and

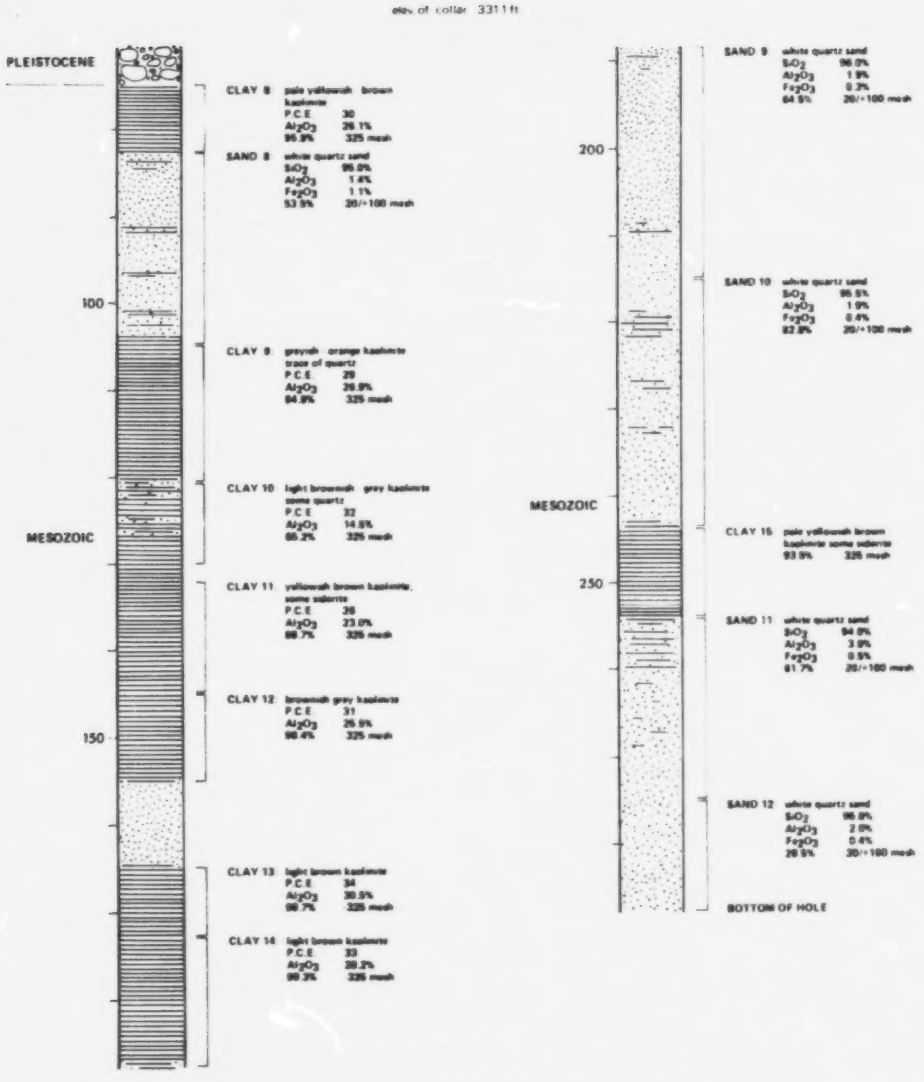

Figure 5.7–Analyses of composite sand and clay samples, drillhole 75-05.

possibly that of chromium in some instances. A favourable grain size distribution is found in sands 9, 10, and 11, while the coarser sands 8 and 12 lend themselves to uses in silica brick and possibly as foundry sand.

The depth to which these potentially favourable sands extend, and their proximity to transportation facilities near Smoky Falls, Harmon Township, makes deposits directly north of the Precambrian escarpment in this area particularly attractive.

DRILLHOLE 75-06

Location:	McCausland Township, central part; on high ground east of Opasatika River, near river crossing.
Depth:	175 m
Log:	Pleistocene 52 m
	Mesozoic 52-140 m
	Paleozoic 140-175 m

Due to the frequently silty nature and high content of impurities of sands in this drillhole (Figure 5.8) only sands in the upper part of the drillhole have been analysed for economic potential. Samples include 70-76 m (sand 13), 76-79 m (sand 14), 84-91.5 m (sand 15) and 91.5-99 m (sand 16).

The geologic history of deposits intersected in drillhole 75-06 has not been determined unequivocally. Although the white quartz sand with transparent, angular to subrounded grains of a wide range of sizes is typical of sands of the Mattagami Formation, the possibility exists that this material has been contaminated with clays and organic debris, possibly as a result of reworking in what is now a buried river valley. Clay samples lack kaolinitic clay which is not found until below a depth of 126.5 m.

The analysed sands have an unfavourable grain size distribution with too high a percentage of either fines and clay (sands 13, 14, and 15) or of coarse material (sand 16) to be useful as a source of glass sand. Impurities include hornblende, chlorite, biotite, magnetite, ilmenite, pyrite, siderite, zircon, and garnet. Red feldspar, white carbonate pebbles and fragments of sandstone occur in sand 16. The presence of carbonates and feldspar, although not detected visually, is also expressed in the chemical analyses of sands 13, 14 and 15. Consequently the sands are also too low in silica content to be of interest as a source of glass sand.

Kaolin and Fireclay

Clays are the fine-grained alteration or weathering products of rock-forming minerals. They are made up of finely comminuted clastic particles and newly-formed minerals. The newly-formed clay minerals are hydrous silicates with a layered crystal structure. Common clay minerals are kaolinitic clay, montmorillonite, and illite or hydromica. Members of the kaolinitic clay group

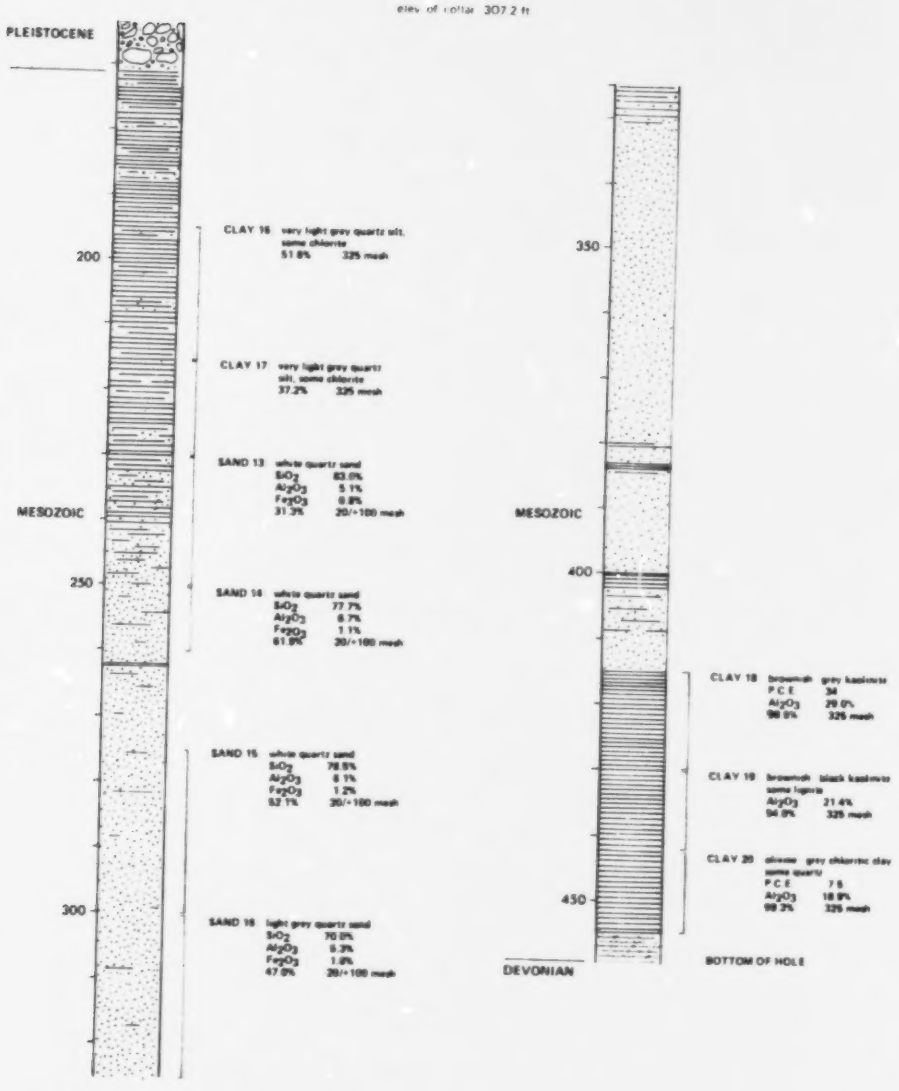

Figure 5.8–Analyses of composite sand and clay samples, drillhole 75-06.

are simple hydrous aluminosilicates; montmorillonites in addition carry iron and magnesium. Illite or hydromica is characterised by the presence of potassium.

Most clays contain more than one clay mineral. Usefulness of clay as a fire resistant or refractory raw material depends on the absence of fluxes like iron and alkalies. Kaolinite is an extremely suitable refractory raw material. At high temperatures it converts to an intergrowth of mullite and silica which imparts strength to the refractory ceramic.

MINERALOGY

Kaolinitic clay or china clay is a white clay consisting predominantly of hydrous aluminosilicates of the kaolinitic clay group. Kaolinite has the formula: $Al_4(Si_4(OH)_8)$. The group includes polymorphs of this composition as well as anauxite, which has a higher silica content, halloysite, with increased water content and meta-halloysite, which develops from halloysite by partial reduction of the water content.

The minerals of the kaolinitic clay group are characterised by a double layer structure. A layer of silica tetrahedrons in hexagonal array at the base is linked to a layer of aluminium hydroxide above by the shared oxygen atoms of the upward pointing tops of the tetrahedrons. Additional water can be accommodated between the hydroxyl groups of the aluminium hydroxide layer and the oxygens of the next layer of silica tetrahedrons. Additional water is present in halloysite, metahalloysite, and in a form of kaolinitic clay with tubular morphology, referred to as hydrated kaolinitic clay (Deer, Howie, and Zussman 1962, p.198).

Kaolinite is white and has perfect basal cleavage. It has hardness of 2 to 2.5 and specific gravity of 2.61. The crystal platelets occur either individually, in American clays usually concurring with grain sizes smaller than 2μ, or they occur stacked in book form or vermicular shape exceeding 2μ in size (Lyons and Bowman 1973, p.27). A third division commonly made is one of "Fines", smaller than 0.25μ. Fines are known to occur in compact masses typical for ball clays. A higher content of montmorillonite, 3 to 5 percent, often serves to make the fines plastic and sufficiently strong for ceramic use.

The degree of stacking order of crystal platelets in books of kaolinitic clay determines its specific use in other instances. Small, well-ordered blocky grains or individual platelets are preferred for paper coating. Extremely thin, small platelets with ragged edges produce a plastic clay for ceramic use. The latter grades are often blended with larger well-ordered crystals (>2 μ) in order to combine plastic strength with shrink resistance (Lyons and Bowman 1973, p.28). Loss of platy habit common in grains larger than 2μ makes these grains unsuitable for paper coating.

ORIGIN AND CHARACTER OF DEPOSITS

The formation of kaolinitic clay is dependent on the breakdown, hydration, and chemical alteration of common rock forming silicates, primarily feldspar. Calcium, alkalies, iron, and magnesium have to be removed. Alteration of rock-forming minerals under slightly acidic conditions leads to accumulation of resistant hydrous aluminosilicate clays. The acidic conditions may be met by surface weathering or by low temperature hydrothermal alteration. Large deposits of residual kaolinitic clay are associated with granitic rocks in Cornwall, England (Industrial Minerals, January 1972, p.9) and kaolinitic clay deposits are derived from such rocks in Georgia and South Carolina, U.S.A. (Industrial Minerals, December 1971, p.9). Deposits in the latter area are comparable in manner of occurrence to deposits in the Moose River Basin. Kesler (1963, p.3) describes how lenses of kaolinitic clay alternate with unconsolidated sands of the coastal plain in Georgia and South Carolina, southeast of a line along which an abrupt change of gradient separates this area from higher ground of the Appalachian Piedmont Plateau to the northwest. The line is characterized by waterfalls and rapids in the rivers and is referred to as the "fall line". According to Kesler (1963, p.4) the Piedmont Plateau is a weakly rejuvenated peneplain which has been eroded to a secondary stage of maturity. It is underlain by granite,quartz monzonite, diorite, gabbroic rocks, and felsic and mafic schists, gneisses, and pyroclastics. The sand derived from the Piedmont Plateau and deposited below the "fall line" is mostly coarse and angular to subangular. Feldspar grains and kaolinitic clay pseudomorphs after feldspar occur in some beds. Smooth pebbles are rare and usually much smaller than 2.5 cm in diameter. The Cretaceous sands rest either on crystalline rock or on Paleozoic formations. They are overlain by Eocene and younger sediments.

Cretaceous sands near the "fall line", where mining takes place, have been exposed by erosion and deposits in the mining area are up to 150 m thick. Lenses of kaolinitic clay have been found to a depth of at least 53 m. Commercial kaolinitic clays occur in two areas only. Kesler (1963, p.7, 8) gives the following details:

> The kaolin deposits are generally lenticular, but rarely symmetrical, and non-uniform thickness is fairly common. In plan, the lenses are mostly elongate and curved or sinuous, although no preferred orientation is evident to date. In major dimension they range from a few feet to perhaps a mile, but uniform quality is rarely found throughout a lens. Vertical thickness ranges from inches to about 50 feet, and many of the mined deposits have averaged 20 feet. Contacts with enclosing sands are mostly gradational, but a few are sharp.
>
> In natural particle size, very little of the kaolin ranges above 10 microns and in the greater part of most deposits it is predominantly less than 2 microns....
>
> Many of the kaolin deposits contain detrital sand and mica in quantity too great for refining, and even the purest contain them in small amounts. Extremely fine-grained heavy minerals are also present, and, of these, titanium minerals have the widest distribution. These detrital minerals, together with fragments of vermicular kaolin crystals, are collectively termed grit in refining, and its amount is commonly determined as residue after washing the kaolin through a 325-mesh screen. For efficient milling, a dry-ground kaolin should contain less than three-percent grit in the crude but much larger amounts may be tolerated in wet refining. With the exception of the grit, the kaolin clay consists almost entirely of kaolinite clay, although traces of montmorillonite are found in some deposits.

Kesler (1963, p.10) ascribes the origin of the quartz sand-kaolinitic clay association to weathering in situ of a feldspathic sand. Minor redistribution in the deltaic environment could have brought about the separation of sand and clay. A temporary influx of seawater at times might have caused deposition of fine-grained, hard kaolinitic clay, while softer clay resulted from slow deposition in the slightly acidic fresh water ponds. Kesler ascribes the low content of ferromagnesian minerals in the sand to initial weathering of these minerals on the Piedmont Plateau. The products would have been carried out to sea as montmorillonite, leaving behind the coarser grained feldspathic sand for deposition in the delatic environment below the "fall line". Kesler (1963, p.11) postulated that the area of particular abundance of commercial deposits, may be related to the location of the major contributing streams.

Recent studies indicate that the quality of kaolinitic clay depends on the type of mineral from which it developed (Lyons and Bowman 1973, p.145). The well-stacked books of crystalline kaolinitic clay, suitable for paper coating, are thought to be the product of micaceous minerals, while poorly ordered kaolinitic clay crystals seem to have derived directly from feldspar. Respective source minerals are associated with kaolinitic clays of different quality in the Georgia deposits and there is a definite regional limitation to the occurrence of deposits of well-ordered kaolinitic clay (Kesler 1963, p.144, 145).

Whether or not the weathering of feldspar passes through a micaceous stage before kaolinitic clay is formed, may depend on the effectiveness of leaching (Grim and Wahl 1968, p.15). An intermediate stage of micas may occur when leaching does not rapidly remove the alkalies from feldspar.

The association of hydromica or illite with calcite was noted by Bondam (1968, p.65). He found that calcite indicates a geochemical trend being part of the illite paragenesis. Calcite is not stable, however, and after its final removal from the weathering residue the trend changes from illite paragenesis to formation of kaolinitic clay and ultimately bauxite. Besides advancing the growth of illite the presence of calcite also raises the stability of potassium feldspar (Bondam 1968, p.70).

Conditions favourable for development of kaolinitic clay deposits are listed by Kuzvarth and Neuzil (1972, p.102, 103). The conditions include suitable parent rock, sufficient energy and time. Thermal and chemical energy are supplied by a warm and humid climate or a low-temperature hydrothermal environment

Necessary are:

a) an acidic aqueous environment (pH 6.4 to 4)

b) an annual temperature varying between 16°C and 18°C and precipitation of about 1000 mm.

c) geomorphological conditions permitting lateral transport and removal of products of kaolinitization (K, Na, Ca, Mg, some SiO_2)

d) for kaolinitization of melanocratic rocks, a higher degree of acidity or the presence of organic matter, which will reduce ferric iron to the more soluble bivalent ferrous form. Kuzvarth and Neuzil (1972, p.101) estimate that in a tectonically quiet environment, without transgression, kaolinitization through weathering progresses downward by 0.01 mm to 0.1 mm annually, or at the rate of 10 m to 100 m per million years. They add that, with depth, this rate will decrease.

Reference was made previously to development of a special clay under coal measures, the so-called underclay. Although the role of vegetative matter in development of these clays is not always clearly understood, the clays are found to consist largely of kaolinitic clay and illite. Underclays beneath coal beds of the Pennsylvanian System provide the bulk of fireclays in the east-central United States. In California both clays and lignite of the Eocene Ione Formation are produced. Here lenses of very refractory clay are found underneath the lignite coal (Bates 1960, p.47, 48, and 125).

Refractoriness of clays is expressed in pyrometric cone equivalent values (P.C.E.). The following distinctions may be made (Bates 1960 p.124):

	Equivalent temperatures at rise of 20°C per hour
Fireclay - PCE >19	>1515°C
Low Duty - PCE up to 28	1615°C
Intermediate Duty - PCE up to 30	1650°C
High Duty - PCE up to 32	1700°C
Super Duty - PCE up to 35	1775°C

Not all underclays are suitable for use as fireclay, however, and many fireclays are made up from other sources, often by blending of clay with bauxite minerals. Tests performed on clays of the Missinaibi River and Onakawana River areas, James Bay Lowland, have shown that the quality of these clays is variable, but that refractory clays with PCE's up to 33 or 34 are frequently found in both locations (Montgomery 1933, p.82, 83; Crozier 1933, p.94).

An analysis of the clay fraction (-325 mesh) of 3 samples of quartz sand-kaolinitic clay from McBrien Township showed that 75 percent or more of the grains are smaller than 2 μ in diameter (Smith and Murthy 1970, p.809). Smith and Murthy (1970, p.809) found that the brightness of a grey clay could be improved, by bleaching with zinc or sodium sulphite, from 67 percent to 82 to 83 percent brightness. The presence of Fe_2O_3 and TiO_2 in some clay samples (Guillet 1967, p.77) suggests that present magnetic beneficiation techniques may achieve similar or better brightness gains.

USES OF KAOLIN

It is normal practice for the clay industry to grade, classify, beneficiate, and blend raw materials from a group of kaolin deposits rather than to sell in bulk from single occurrences. The following discussion of uses is based on information in the magazine Industrial Minerals (December 1971, p.12-15).

In the manufacture of ceramic products kaolin contributes plasticity, dry strength, and desirable firing characteristics to structural clay, refractoriness to alumina refractories, desirable fired colour to whiteware, and fineness and plasticity to porcelains combined with a desirable low electrical conductivity.

Kaolin as a filler in rubber serves to either harden the rubber, as in footwear, or to lower the elasticity and improve abrasion resistance, which is achieved by using softer grades of kaolinitic clay as in floor tile. In plastics, use

of kaolin is most promising in the glass reinforced polyesters where it imparts good flow characteristics. It is particularly well suited as a filler in latex paints since the washed grades wet easily in water. It has good opacifying qualities and is useful as an extender of pigments in paints.

In paper manufacture kaolin serves both as a filler, to fill interstices between pulp fibres and as a coater, to produce a smooth glossy surface. It has good affinity for printing ink, high gloss, and brightness and can be applied in near-dry state, allowing fast production methods. Kaolin may constitute up to 20 percent by weight of a glossy magazine paper. Both air-floated and water-washed grades of kaolin are produced. Only the water-washed grades are sufficiently bright and pure for use in paper manufacture.

Previous Studies

Recognition of refractory clays in the Moose River Basin before the turn of the century was followed by examination of the deposits by government geologists after World War I (Keele 1920; Montgomery and Watson 1929; Dyer and Crozier 1933). The principal results of these investigations have been compiled in Appendix 5.1.

Moose River Basin Studies 1975

In drillhole 75-03, 65 km north of the Precambrian escarpment, 18.2 m of quartz sand and green, red-brown, and grey clay were encountered at a depth of 116.3 m (Telford, this report). The clay in this location is primarily illite. Kaolinite does not occur in abundance until approximately 35 km to the south where it is found in outcrops in the bed of the Missinaibi River and in drillhole 75-01. The distinction between illitic and kaolinitic clays correlates, at least in part, with the distinction between Middle Jurassic Mistuskwia Beds and the Lower Cretaceous (Albian) Mattagami Formation (Telford *et al.* 1975, p.19).
Sampling and analysis of clay in the 1975 drillholes was designed for the dual purpose of acquiring geologic information and establishing economic potential. Economic potential is limited to clay beds of a certain minimal thickness. For this reason composite samples were arbitrarily selected as shown on Figures 5.5-5.8. Additional samples were obtained from quartz sand where the clay fraction (-325 mesh) exceeded 5 weight percent. With one exception these samples consisted of fine quartz silt without a clay mineral component. The exception concerns a sample in drillhole 75-02 (sand 4). Clays in drillhole 75-02 are characterized by the minerals chlorite, illite, and expanding clay minerals; kaolinitic clay was not found.

The drilling process (reversed circulation chip drilling) caused loss of kaolinitic clay associated with quartz sand. An attempt at recovering this kaolinitic clay was made in some instances by collecting samples of overflow water where suspended clay turned this water excessively white. Analysis of these samples showed an abundance of well crystallized kaolinitic clay with bright-

ness values up to 91. It can be concluded from the analytical results that potential high-grade filler clays occur in association with quartz sand; very little of this higher grade kaolinitic clay has been preserved by the sampling procedures. Large amounts of kaolinitic clay are concentrated in individual clay units of sufficient thickness to be mined separately. The analyses of composite samples representing these units show potential for ceramic clay or high grade (super duty) fireclay (P.C.E. +32) but they fail to meet the standard of brightness required of high-grade filler clay.

The following discussion is based on analytical results (Moddle 1976):

Kaolinite was the major component of the majority of samples. It appears to be well crystallized and tends to dominate over minor amounts of quartz, chlorite, and illite. The -2 μ fraction tended to have more kaolinitic clay than the +2 μ. Chlorite generally was poorly crystalline with indistinct peaks. Chlorite content tended to be consistent in the 2 μ and -2 μ fractions. Illite was more pronounced in the -2 μ fraction. It was poor to well crystalline. Expanding layer clays are rare and are a minor component. It is suspected that chlorite forms a major constituent of these mixed layers because of large amounts of chlorite found in the same sample.

The clays were generally uniform in colour save many of the olive grey (5Y 5/1) varieties which were mixed with red and green layers (often interbedded). It was found that maximum beneficiation was possible with the addition of 0.5 g of bleach for every 100 g of sample. The bleaching serves mainly to remove Fe^{+3} iron.

A striking difference exists between clays north of the Missinaibi River area (drillholes 75-02 and 75-03) and clays in and south of the Missinaibi River area (drillholes 75-01, 75-05, and 75-06). Dark green and grey clay associated with quartz sand in the intervening hole (drillhole 75-04, sand 6 and 7) has not been analysed separately. The dark green color noted in the drill log (Rogers *et al.* 1975) suggests affinity of this clay to the northern clays.

DRILLHOLE 75-02.

Clay was intersected in this hole at depths of 104.8 - 105.8 m (clay 3) and 108.6 - 113.8 m (clay 4). In addition, the clay fraction of sand 4 (drillhole 75-02, 101.5 - 104.6) has been analysed.

Clay 3 is a pale yellowish-brown illite clay with minor calcite and chlorite. Dolomite, organic clasts, some biotite and pyrite form part of the +325 mesh fraction of this sample. The clay has low refractoriness (PCE = 2), low brightness (29.9%), and occurs at too great a depth to be of economic importance.

Clay 4 is an olive grey montmorillonite with some dolomite and minor illite, calcite, chlorite, mica, and pyrite. Brightness (31.2%) refractoriness (P.C.E. = 3), and alumina content (12.4%) are low. The clay at this depth has no economic significance.

The clay fraction of sand 4 (8% -325 mesh) contains appreciable amounts of chlorite, illite, and expanding clay and is similar in this respect to the underlying clays 3 and 4. It is the only clay fraction obtained in routine analysis of sands which does not consist primarily of quartz.

DRILLHOLE 75-03.

Clay was intersected at depths below 118.8 m and sampled as follows:

clay 5	124.3 - 126.2 m
clay 6	126.2 - 131.7 m
clay 7	131.7 - 135.7 m

Clay 5 is an olive grey illite with traces of chlorite and calcite. In the coarse fraction some calcite-cemented sandstone, pyrite, and gypsum occur. Low refractoriness (P.C.E. = 2.5) and low alumina content (13%) render this clay uninteresting economically.

Clay 6, a greenish grey illite, has a refractoriness and alumina content slightly lower than clay 5. Crystalline limestone, biotite. and pyrite are found in the coarse fraction.

Clay 7, a light brown illite, is very similar to clay 5 except for color. In the coarse fraction much carbonate and some biotite, feldspar, pyrite, and siderite occur. Refractoriness and alumina content (13.3%) are almost identical to clay 5.

The deeply buried clays north of the Missinaibi River rank as low-grade plastic clays and are probably suitable as raw material for the manufacture of brick, tile or pottery. Their characteristics do not justify mining at this depth.

DRILLHOLE 75-01.

Drilled on the bank of the Soweska River near the northwest corner of Hambly Township and north of the Missinaibi River, this hole intersected 32.9 m of Mesozoic sands and clay.

The clay intersections sampled are:

clay 1	28.6 - 31.4 m
clay 2	37.1 - 43.8 m

Clay 1 is a reddish brown kaolinitic clay with a high percentage (>20%) of quartz concentrated in the coarse fraction. A sieve analysis of this fraction showed a very even spread of coarse grains in the glass sand range (-20 + 100 mesh). The clay is a high duty fireclay (P.C.E. 31). Plasticity index (14) and brightness (28.7%) are low, detracting from its potential as a ceramic clay. A high alumina content (23.9%) confirms the high content of kaolinite. Hematite, limonite, and some biotite are the only additional minerals recorded in this section.

Clay 2 contains the reddish brown kaolinitic clay of clay 1 combined with a much larger amount (>45%) of quartz silt and sand. A sieve analysis indicated that 19.5% is coarser than desirable for glass sand. A medium plasticity reduces the usefulness of the clay fraction. Nevertheless, thorough size grading may produce suitable glass sand and fireclay (P.C.E. 32) from this source.

The encouraging aspect of deposits in this location is their possible extent in depth. A total thickness of 140 m of Mattagami Formation deposits is indicated in the geophysical profile and this is consistent with results of drilling and geophysical studies to the south.

DRILLHOLE 75-06.

In the central part of McCausland Township, 21 km southeast of drillhole 75-01, a hole was drilled at the winter-road crossing of the Opasatika River. Mattagami Formation sands and clays (88 m) were intersected from a depth of 52 m to the contact with Devonian shales at about 140 m. Two samples (clay 16 and clay 17) taken near the top of this section proved to be largely quartz silt with some chlorite, illite, and plagioclase. The absence of kaolinitic clay suggests that the material was reworked or deposited after kaolinization had taken place. The quartz silt is too fine for use as glass sand.

Clay 18 (127.7 - 132.6 m) is a brownish grey kaolinitic clay with super-duty refractory characteristics (P.C.E. 34), a high alumina content (29% Al_2O_3) and medium plasticity. Lignite and oolitic siderite occur in the coarse fraction. The clay may be best suited to upgrade less refractory but more plastic clays.

Clay 19 (132.6 - 135.7) is brownish black kaolinitic clay with an appreciable amount of lignite (estimate: 3%) and some quartz. With a high refractoriness (P.C.E. >34) and higher plasticity than clay 18, clay 19 enhances the usefulness of the combined intersection of 8 m of clay near the base of drillhole 75-06.

Clay 20 (135.7 - 140 m) is an olive grey chloritic clay occurring within a few metres of the contact with Devonian shales. Its character reflects much closer the composition of these shales than of the fireclays of the Mattagami Formation. Kaolinite is absent. A low refractoriness (P.C.E. 7½) and low alumina content (18.9% of Al_2O_3) restrict the economic potential of this clay.

DRILLHOLE 75-05.

Approximately 4 km north of the Precambrian escarpment, where the winter-road crosses the Waboose River in Acres Township, this drillhole was drilled to a depth of 88 m. Mattagami Formation deposits were intersected from 22.5 m to the bottom of the hole. Geophysical results indicate that at least another 60 m of Mesozoic deposits may be expected.

In terms of economic potential, drillhole 75-05 presents the most interesting section. Sampled almost in its entirety, eight clay samples and five sands were collected and analysed. The clay samples represent a total thickness of 27.25 m of kaolinitic clay.

Clay 8 (23.1 - 26.2 m) is a pale yellowish brown kaolinitic clay with minor mica and feldspar in the coarse fraction. Whether or not this clay is suitable as ceramic clay for whiteware production depends on firing characteristics (e.g. burnt color). It has low brightness (23.3%) and medium plasticity. The alumina content is 26.1 percent; the refractoriness (P.C.E. 30) is characteristic of high duty fireclay.

Clay 9 (32.3 - 37.2 m) is a greyish orange kaolinitic clay with some quartz, illite, and traces of muscovite and limonitic siderite. The refractoriness (P.C.E. 29) corresponds with intermediate-duty fireclay.

Clay 10 (37.2 - 40 m) is a light-brownish-grey sandy kaolinitic clay. The low

alumina content (14.5% of Al_2O_3) and high refractoriness (P.C.E. 32) reflect the quartz-rich nature of its sandy fraction (34.8% +325 mesh). In this context the plasticity is surprisingly low. This clay lends itself to either blending or beneficiation since very little deleterious material is present. Only the physical characteristics (e.g. size grading) need to be improved.

Clay 11 (40.8 - 44.6 m) is a yellowish-brown kaolinitic clay with a substantial amount (>5%) of oolitic siderite. The predominance of this siderite in the coarse fraction suggests that beneficiation will improve brightness (26.3%), refractoriness (P.C.E. 26) and alumina content (23%).

Clay 12 (44.6 - 47.7 m) is a brownish grey kaolinitic clay which seems to be colored mainly by the presence of lignite (0.8%). The refractoriness is high (P.C.E. 31) and the percentage of coarse material low (1.6% +325 mesh). Testing of the firing characteristics is necessary to determine possible uses for this clay.

Clay 13 (50.8 - 53.1 m) is a light brown kaolinitic clay with a high content of alumina (30.5% of Al_2O_3) and a correspondingly high refractoriness (P.C.E. 34). In the coarse fraction (0.3% +325 mesh), minute quantities of siderite and hematite occur. A brightness of 25.7% suggests that testing for firing characteristics (burnt color) is necessary to determine the ultimate use of this high quality clay.

Clay 14 (53.1 - 57.5 m) is a light-brown kaolinitic clay with characteristics very similar to Clay 13. Clays at this level should be treated as one unit with a total thickness of 6.7 m.

Clay 15 (75.4 - 78.5 m) is a pale-yellowish-brown kaolinitic clay with medium plasticity. The coarse fraction (6.5% +325 mesh) contains quartz, muscovite, and siderite in almost equal percentages. Bleaching raises the brightness of clay 15 from 29.2% to 38%. Refractoriness and alumina content have not been determined.

CLAY FROM WATER SAMPLES

The sampling routine in the reverse circulation wet-drilling process called for sampling overflow drill water when the milky color indicated excessive loss of a fine clay fraction. This sampling was aimed at recovering some of the white kaolinitic clay frequently associated with quartz sand in the Mattagami Formation. The presence of this clay is repeatedly mentioned in drill logs (Rogers *et al.* 1975). The following samples were taken and analysed:
Drillhole 75-01 — (sand 1) 14, 15; (sand 2) 20, 22;
(sand 3) 23, 24, 25; 36, 38, 42, 45.
Drillhole 75-05 — (sand 9) 79.

In both drillholes clay associated with quartz sand is predominantly kaolinitic clay of excellent crystallinity with fine quartz. In the upper part of drillhole 75-01 (samples 14, 15, 20) there are, in addition, minor amounts of calcite and dolomite. Brightness of these clays has been determined for samples 01-23, 24, 25, 42 and 05 - 79. It ranges from 71.1 percent in sample 01-42 to 91.1 percent in sample 05 -79.

These results contrast sharply with analysis of clay retained with sand in

routine sampling. In 4 out of 5 samples in which size analysis of sand indicated the presence of a substantial amount of clay (-325 mesh) the results showed that this "clay" fraction consisted almost exclusively of fine quartz. The exception occurred in drillhole 75-02 (sand 4).

Summary

Results of drilling, outcrop studies, and geophysical surveys in the Moose River Basin support the view that continuous deposits of quartz sand and kaolinitic clays of Lower Cretaceous age (Mattagami Formation) underlie an area 20 to 30 km wide and 85 km long that lies north of the Precambrian escarpment and extends in length from Burstall Township in the west to Kipling Township in the east. The thickness of this formation ranges from 86 m to greater than 120 m. Although present data are incomplete, it appears that a volume of approximately 212.5 km^3 of quartz sand, kaolinitic clay and fireclay may be involved. At an average specific gravity of 1.95, this volume amounts to 4×10^{11} tonnes of sand and clay of potential commercial value. In the event of even producing only one percent of this material at a profit of one dollar per ton, a total of four billion dollars would be added to the mineral revenue of Ontario. Development of these deposits to provide for Ontario production of paper in a variety of qualities besides newsprint, to enable production of glass and refractory ceramics from predominantly local mineral resources, and to possibly support an Ontario whiteware industry, opens up perspectives of importance to the Ontario economy.

Gypsum

Gypsum deposits of the Moose River Basin provide some of the most spectacular rock exposures in Ontario. Outcrops of massive white gypsum occur over a distance of 65 km along the northwesterly-trending Moose River arch (Figure 5.9). They are known from the Cheepash River, the Moose River crossing area, Gypsum Mountain, and the French River. Due to their high purity these deposits have attracted considerable attention. They were first mentioned by Robert Bell (1877) and a general description was given by Dyer (1929) and more recently by Guillet (1964; 1967).

GEOLOGY

In the James Bay Lowland gypsum occurs at intervals throughout the Paleozoic sequence. Major known occurrences, however, are confined to the Moose River Formation, a Middle Devonian formation correlated by Sanford *et al.* (1968) with the Lucas Formation of the Michigan Basin. Underlying the Moose River Formation are thick-bedded coralline limestones of the Kwataboahegan Formation, equivalent to the Amherstburg Formation of the Michigan Basin.

Light brown crinoidal limestone of the Murray Island Formation disconformably overlies the gypsiferous beds. Much of this limestone is brecciated, presumably due to collapse into gypsum solution cavities.

Guillet (1967) described the gypsum as generally white, massive, fine to medium grained, and of high purity, with samples consistently averaging more than 90 percent gypsum. The following details are taken from his report:

CHEEPASH RIVER OCCURRENCES

In Roebuck Township gypsum is almost continuously exposed for 9 km along the Cheepash River. The river banks expose up to 8 m of white, medium-grained, massive, colloform gypsum with very minor amounts of brown limestone laminae. During the fall of 1963, Moosonee Gypsum Company carried out a drilling program that proved the continuation of the gypsum to a depth of 38.5 m (Figure 5.9). Their drilling also confirmed an extremely scalloped gypsum surface caused by deep glacial gouging and solution.

MOOSE RIVER CROSSING

Gypsum, gypsum breccia, and limestone are continuously exposed in both river banks over a distance of 4 km on the downstream side of the Moose River railway crossing. Gypsum is also exposed for 0.4 km on the southeast shore, 11 km downstream from the railway bridge. The outcrops consist typically of 3 to 5 m of gypsum-limestone breccia overlying and in sharp contact with 1 m of wavy bedded, resinous-brown and white, coarsely recrystallized selenitic gypsum. Massive, medium grained, white gypsum, containing numerous "eyes" and healed fractures of recrystallized brown selenite, and minor thin limy laminae, underlie the brown and white gypsum zone. Thin-bedded, fine-grained brown limestone overlies the gypsum sequence near the extremities of the gypsum outcrop areas. On the northwest shore the terraced river bank is 8 m high, the upper 3 m (above the gypsum sequence) consisting of till and river sands. On the southeast shore the bank is 15 m high, of which 6 to 8 m is overburden.

In 1929 the James Bay Basin Oil Company Limited drilled three holes on the islands upstream from the Moose River bridge. One at the head of Mike Island, 3 km upstream from the last gypsum outcrop, encountered gypsum interbedded with shale and limestone through a vertical range of 60 m. Another, drilled at the head of Murray Island, almost opposite the last gypsum outcrop, intersected 30 m of gypsum. The section indicated by the latter hole is illustrated in Figure 5.10.

GYPSUM MOUNTAIN

White, massive, sugary gypsum, in banks 5-6 m high, outcrops above the muskeg near the east boundary of Stapells Township. The occurrence, known

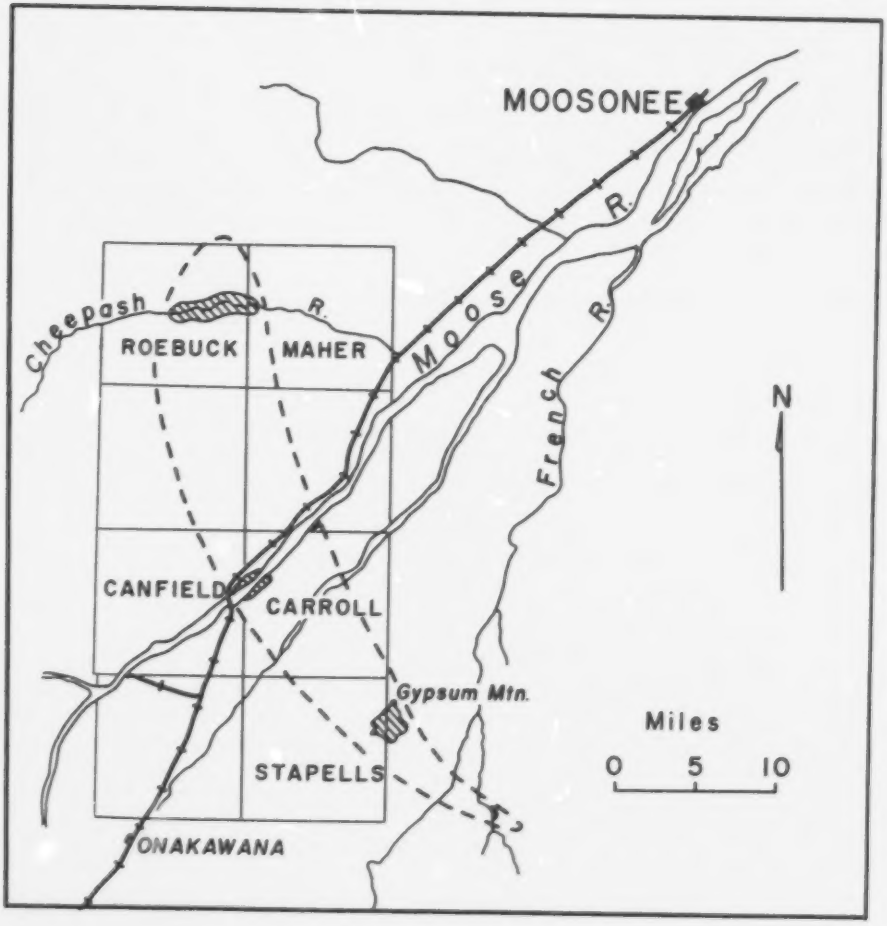

Figure 5.9–Outcrops of gypsum in the Moose River Basin.

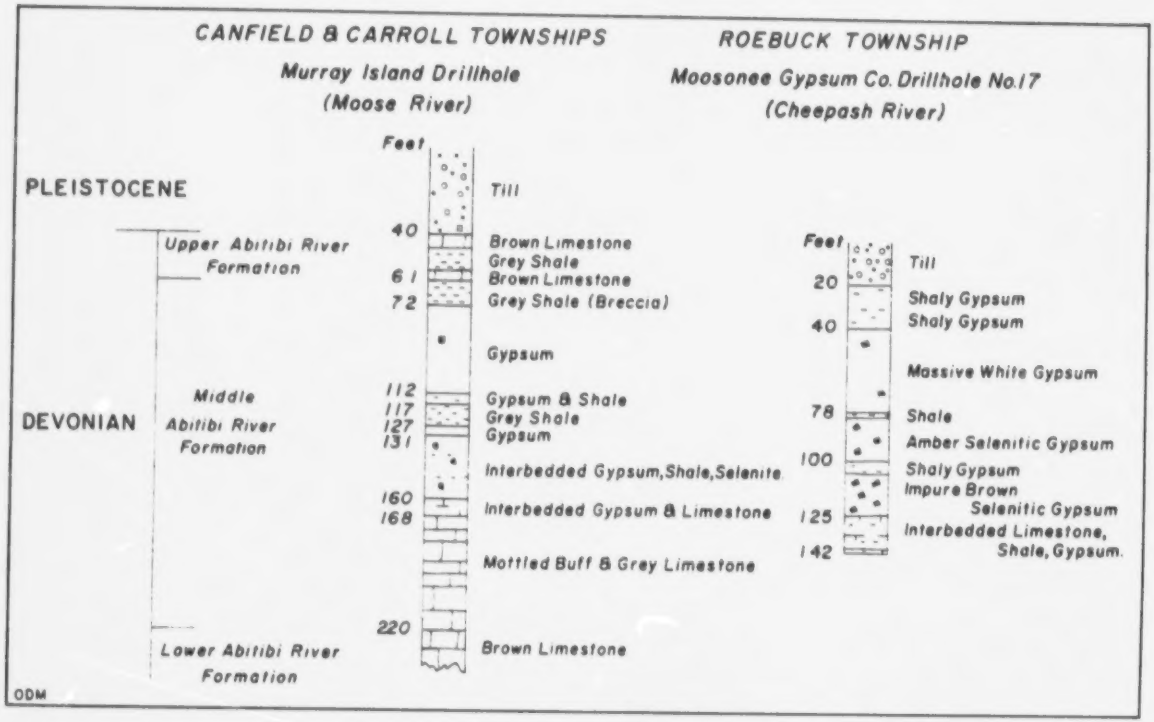

Figure 5.10–Geologic Sections of Moose River Basin.

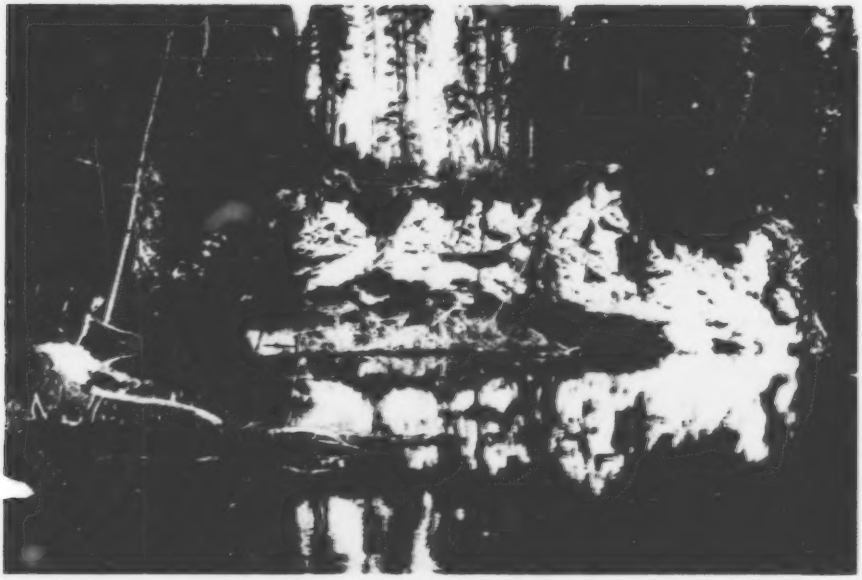

Photo 5.1–Photograph showing a natural arch of gypsum in the Gypsum Mountain area.

as "Gypsum Mountain", covers an area of about 10 km^2. An interesting weathering feature is the occurrence of a series of natural arches, 18.5 m or more across, that have formed by solutioning along two watercourses that transect the area in north-south and east-west directions (Photo 5.1). Gypsum Mountain represents the peak elevation of the gypsum sequence above sea level.

FRENCH RIVER

Several small outcrops of gypsum occur over a distance of 0.4 km on the east bank of the Wakwayowkastic River, central branch of the French River. The outcroppings expose a 2 to 3 m section of good quality white, finely granular, massive gypsum with traces of grey-black, crenulated, limestone laminae.(Guillet 1967).

APPENDIX 5.1.

Review Data on Refractory Clays.

Notes
1) Keele 1920
2) Montgomery and Watson 1929
3) Montgomery 1930
4) Crozier 1933
For detailed results see original literature
For locations see Figure 5.4

LOCATION: 1 (Douglas Property, Kipling Township)

Sample[1)]	Description	Raw Colour	Fired Colour	%-200 Mesh	P.C.E.	Max. Depth Sampled
(1) - 5		black	white		33-34	
- 6		white	white		33-34	
- 7		light grey	cream		33-34	
(2) - 96	smooth, good plasticity	light grey	light buff	97	32	
- 94	sandy, good plasticity	near-white	grey white to light buff	80.7	31	
- 97	smooth, good plasticity	grey brown	pink to buff	94.5	31	
- 103	smooth, good plasticity	slate grey	grey white to light buff	98.9	31	12 feet
- 100	sandy, fair plasticity	mottled grey and buff	buff	77.1	29	
- 102	smooth, good plasticity	buff	red to dark brown	99.2	28	
- 95	sandy, low plasticity	buff	buff	38.7	27	

1) (1) Keele 1920
(2) Montgomery and Watson 1929

LOCATION 3, 4: (Grand Bend, Mattagami River)

Sample[1]	Description	Raw Colour	Fired Colour	%-200 Mesh	P.C.E.	Max. Depth Sampled
(3) - C	Smooth, good plasticity	dark grey	light buff to grey		33	
- D	Smooth, good plasticity	dark grey	buff		32½	
(2) - 74	Smooth, good plasticity	light grey	grey white to dark	96.1	32	
- 75	Smooth, good plasticity	grey	grey white to buff	98.8	32	
- 76	Smooth, good plasticity	dark grey	grey to buff	52.6	32	
- 78	Smooth, good plasticity	light grey	grey white to buff	94.9	31½	
- 69	Smooth, good plasticity	slate grey	light to dark buff	85.5	31	
- 77	Smooth, fair plasticity	dark grey	grey white to light buff	98.4	31	
- 73	Smooth, good plasticity	light grey	grey white to dark brown	91.6	30	
- 27	Smooth, good plasticity	medium grey	light to dark grey	98.0	30	
- 40	Sandy clay with lignite fragments	grey	light to dark grey		29	
- 79	Clay from base hole in bottom of shaft	dark grey	. . . . . not tested			122 feet
(3) - E	Smooth, good plasticity	dark grey	light buff to dark grey	90.8	23	

1) (2) Montgomery and Watson 1929
(3) Montgomery 1930

LOCATION 5: (Burstall Township, Missinaibi River)

Sample[1)]	Description	Raw Colour	Fired Colour	%-200 Mesh	P.C.E.	Max. Depth Sampled
(4) - 11	clay, mottled	red, brown and grey			16-17	
- 9	clay	red, grey and brown			11-12	
- 12	clay	red, grey and brown			9	
- 10	clay	red, brown and grey			8	14 feet

1) (4) Crozier 1933

LOCATION: 6, 7 (Coal Creek)

Sample[1)]	Description	Raw Colour	Fired Colour	%-200 Mesh	P.C.E.	Max. Depth Sampled
(2) - 15	smooth, good plasticity	dark brown to black	light to dark grey	99.2	31	
- 19	smooth, good plasticity	dark brown to slate grey	light grey to buff	99.0	30	10 feet
- 16	smooth, good plasticity	black	light grey to buff	97.3	29	
- 18	smooth, good plasticity	black	light grey to buff	99.2	29	
- 14	smooth, good plasticity	light buff to pinkish grey	light to dark grey	92.4	28	
- 67	smooth after crushing to 20 mesh; fair plasticity	light buff	red to dark brown	65.9	16	
- 63	smooth, good plasticity	light greenish buff	red	96.5	10	
- 65	smooth, good plasticity	light greenish buff	red	92.6	9	

1) (2) Montgomery and Watson 1929

LOCATION 8: (Algocen No. 1 Orebody)

Sample[1]	Description	Raw Colour	Fired Colour	%-200 Mesh	P.C.E.	Max. Depth Sampled
(2) - 48	gritty, low plasticity	near white	grey white to light buff	79.6	32	
- 52	smooth, good plasticity	mottled white, red and buff	pink to buff	85.4	32	
- 58	short, fair plasticity	near white	near white to buff	86.4	32	
(4) - 8		white			32	25.3 feet
(2) - 54	short, sandy, fair plasticity	light buff, red stain	light to medium buff	87.5	30	
(4) - 3	sandy	light grey			29-30	
- 7	sandy	light grey			29-30	
(2) - 56	short, sandy, low plasticity	mottled red white and buff		48.0	29	

1) (2) Montgomerty and Watson 1929
(4) Crozier 1933

LOCATION 9: (Algocen No. 2 Orebody)

Sample[1)]	Description	Raw Colour	Fired Colour	%-200 Mesh	P.C.E.	Max. Depth Sampled
(2) - 59	fine grained, smooth good plasticity	red, mottled	red to dark brown	98.8	32	12½ feet

1) (2) Montgomery and Watson 1929

LOCATION 10

Sample[1)]	Description	Raw Colour	Fired Colour	%-200 Mesh	P.C.E.	Max. Depth Sampled
(4) - 17		white, grey				
- 25		white, grey			34-35	
- 19		grey white, some red and brown			34-35	
- 21		white grey			33-34	
- 36		red and grey			33-34	
- 37		fairly white			33-34	
- 24		white grey			33-34	
- 33		light grey and brown			33-34	
- 22		whitish grey			33-34	
- 2 (loc.C)	plastic	grey brown			33	
- 26		light grey brown to grey white			33	
- 34	plastic	black grey			32-33	
- 20		red, grey and brown			32-33	
(2) - 45	smooth, fair plasticity	near white	white some iron spots at higher temperature	99	32-33	
(4) - 13	plastic	black and brownish grey			32½	
- 16		red and brown			32	
- 18		red, grey and brown			32	
(2) - 46	smooth, good plasticity	pink or red stained	pink to grey buff	99.6	32	24.6 feet
(4) - 23	micaceous	grey			32	
- 32		light grey			32	
- 28	sandy, micaceous	light grey, some brown			32	

Continued.....

LOCATION 10 (continued)

Sample[1)]	Description	Raw Colour	Fired Colour	%-200 Mesh	P.C.E.	Max. Depth Sampled
- 14		grey white, red and brown			31-32	
- 31		red, grey and brown			31-32	
- 15		red and brown, some white			31	
- 27		red, grey and brown			31	
- 29		red and grey			31	
- 30		red, brown and mauve			30	

1) (2) Montgomery and Watson 1929
(4) Crozier 1933

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